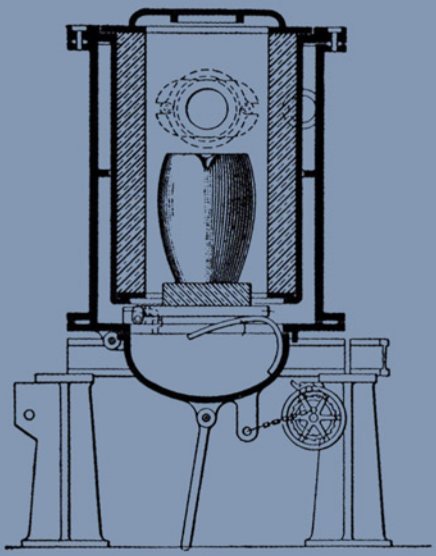

BRASS and ALLOY FOUNDING

by H.B. Maynard

Brass and Alloy Founding

By

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BRASS AND ALLOY FOUNDING
Parts 1–2

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BRASS AND ALLOY FOUNDING

(PART 1)

Serial 2331A Edition 1

METALS AND MOLDING

INTRODUCTION

1. General Remarks.—Brass is an alloy composed chiefly of copper, zinc, and tin, but the term *brass founding* is commonly understood to include the founding of other metals, such as aluminum and any alloys that contain little or no iron. This meaning will be understood to apply in this Section.

Brass founding presents several difficulties not commonly encountered in iron and steel founding. Some of the metals used in brass founding melt at a rather high temperature, whereas other metals, that are to be alloyed with them, melt at a much lower temperature and in some cases will be volatilized at the higher temperature. A metal that volatilizes at or below the melting temperature of the metal with which it is to be alloyed can be retained in the alloy only by using especial care in making and handling it.

2. Segregation.—When metals that melt and solidify at very different temperatures are mixed, the metal that melts at the highest temperature will solidify first and the metal or metals that solidify at lower temperatures will tend to separate out and form globules or patches in the main body of metal. This action is called *segregation*. The segregation of any metal indicates that more of that metal has been supplied than will alloy with the other metals. The remedies are to add something that increases the proportion in which the metals alloy or to reduce the amount of the metal that does not alloy. Tin, lead, and zinc are especially liable to segregate, and alloys containing them must therefore be made with care.

NON-FERROUS METALS

COPPER-ZINC ALLOYS

3. Brass.—Alloys of copper and zinc and alloys in which these metals are the chief constituents are commonly called *brasses*. There are, however, some exceptions to this rule, as, for example, Tobin bronze.

Brass varies in color from red to white. Intermediate between the red and the white brasses are a series of yellow brasses. In general, the more copper there is in the brass, the redder it is, and as the amount of copper becomes more nearly equal to the amount of zinc in the alloy, the alloy changes to a yellow color. An alloy of copper and zinc is not very fluid and a little tin is therefore added to increase the fluidity.

TABLE I

COMPOSITION OF BRASSES

Name or Color	20-Per-Cent. Manganese Copper Per Cent.	Copper Per Cent.	Zinc Per Cent.	Tin Per Cent.	Lead Per Cent.	Aluminum Per Cent.	Nickel Per Cent.
Red brass		87	7.5	2.5	3.0		
Admiralty metal, yellow		70	29.0	1.0			
Yellow brass		65	33.0	2.0			
White brass		31	69.0				
Aluminum brass		72	17.5			9.75	.75
Manganese brass ...	1	75	18.4	5.0		.60	

The addition of lead to brass alloys reduces the cost, increases the density, and makes an alloy that is easily machined. When a casting is to withstand water, gas, or air pressure, a brass containing lead should be used.

4. Composition of Brasses.—In Table I are given the compositions of some brasses.

COPPER-TIN ALLOYS

5. Bronzes.—Copper-tin alloys are known as *bronzes.* Commercial bronzes may carry as much as 15 per cent. of tin, and to most of them zinc is added to make sound castings. A small percentage of lead is sometimes added to make the bronzes easier to machine. The bronzes given in Table II are recommended by good authorities.

When alloying copper, tin, and zinc, they may be melted and mixed in the following order: The zinc may be melted first, and the tin added to it, and then cast into ingots. The proper quantity of this zinc-tin alloy may then be added to the melted copper. Suppose that 100 pounds of the hydraulic bronze were to be prepared. It would be first necessary to melt 3 pounds of zinc and to add to it 8 pounds of tin, making 11 pounds of zinc-tin alloy, which must be added to 89 pounds of melted copper. The copper should, however, be melted under a covering of powdered charcoal or coke.

TABLE II

BRONZES

Designation	Copper Per Cent.	Tin Per Cent.	Zinc Per Cent.	Magnesium Per Cent.
Hydraulic bronze	89	8.00	3	
Gun metal	90	10.00		
Yellow bronze	91	8.96		.04
Original gun bronze	88	10.00	2	

When the yellow bronze is being made, the magnesium and tin may be alloyed and the magnesium-tin alloy added to the copper under a covering of charcoal or coke.

6. Bell Metals.—Bell metal is, as its name indicates, used for the casting of bells. The composition of different bell metals varies a good deal. The composition of some bell metals and the service for which they are adapted is given in Table III.

7. Phosphor-Bronze.—Phosphor-bronze is suitable for a variety of purposes. Phosphorus removes oxygen and other injurious gases from the alloy and any phosphorus in excess of the quantity required for this purpose, alloys with the metal. Phosphorus reduces the strength of the metal, but increases its hardness and wearing qualities. Table IV gives the composition of some phosphor-bronzes. The letters at the head of the columns designate alloys that are suitable for various purposes, as explained in the following paragraphs:

TABLE III

BELL METALS

Qualities	Copper Per Cent.	Tin Per Cent.	Other Metals Per Cent.
Standard metal, excellent tone.	78.0	22.0	
Founder's standard, not so good	77.0	21.0	Antimony, 2
Rich deep tone, house bells ...	80.0	20.0	
For large bells, also small house bells	75.0	25.0	
German clock bells	73.0	24.3	Zinc, 2.7
Swiss clock bells	74.5	25.0	Lead, .5
Table bells	2.1	97.3	Bismuth, .6

A is an alloy suitable for valves, valve stems, and parts of machinery that are in constant vibration. It resists corrosion.

B is an alloy used for hydraulic machinery, valve and piston rods, cylinder linings, and bolts. It is said to be especially good for gears.

C is an alloy used for castings that must resist wear and corrosion. It is hard, dense, and non-corrodible.

D is an alloy that is very dense and almost as hard as steel. It is especially well adapted to castings that must resist wear.

E is a strong, hard alloy that resists corrosion. It is used for bearings, slides, etc.

F is an alloy used to make bells of fine tone that are not liable to crack. For this purpose it is better than bell metal.

G is a very tough and strong alloy. The metal may be made so very dense by hammering that it is impervious to water even at the highest pressures. It is therefore especially adapted for piston rods and linings to pump cylinders.

H is an alloy used for bearings under cars, locomotives, and the bearings of heavy machinery. It wears well and will not injure the shaft, even when running hot.

Phosphorus is seldom added to an alloy in excess of 1 per cent., because the resulting alloy is so brittle as to be of but little use.

8. From one-fourth to one-half of the phosphorus that is put in a charge of metal is usually burned and therefore lost. In order to retain in the metal the amount of phosphorus that is specified in Table IV, from one and one-fourth to one and one-half times that much of phosphorus must be added. When phosphor copper or phosphor tin is used, this allowance need not be made. When it is desired that the alloy be accurately proportioned, the quantity of copper or tin added with the phosphorus must be allowed for in the following manner: Let it be required to find the weights of the metals that will be required to make up 500 pounds of alloy D in Table IV, using phosphor copper containing 10 per cent. of phosphorus.

TABLE IV

PHOSPHOR-BRONZES

Metal	A	B	C	D	E	F	G	H
Copper	92.25	89.25	89.90	84.55	89.40	81.11	94.14	79
Tin	7.25	10.00	9.49	14.52	9.93	18.66	5.18	12
Lead					.41			8
Phosphorus	.50	.75	.61	.93	.26	.23	.68	1

The first thing to do is to find the weight of phosphorus as follows: 500×.93÷100=4.65 pounds. The weight of phosphor copper that will contain 4.65 pounds of phosphorus is 4.65×100÷10=46.5 pounds. Since 46.5 pounds of phosphor copper contain 4.65 pounds of phosphorus, it will also contain 46.5−4.65=41.85 pounds of copper.

The alloy is to contain 84.55 per cent. of copper, or 500 ×84.55÷100=422.75 pounds. Since 41.85 pounds of copper have been alloyed with the phosphorus, there remains 422.75 −41.85=380.9 pounds to be added. The weight of the tin is 500×14.52÷100=72.6 pounds.

These calculations may now be checked by adding the weights of the various metals and seeing that the total weight equals that of the proposed charge, as follows:

	POUNDS
Weight of copper	380.9
Weight of tin	72.6
Weight of phosphor copper	46.5
Total weight	500.0

9. Manganese Bronze.—Manganese bronze, also called *Parsons bronze,* is suitable for large castings that have no intricate parts. Usually it is not profitable to make small castings of manganese bronze. Large castings of manganese bronze should usually be made in dry-sand molds, although castings of moderate size may be made in green sand.

TABLE V

MANGANESE BRONZES

Metal	Formula No. 1 Per Cent.	Formula No. 2 Per Cent.	Formula No. 3 Per Cent.
Copper	58.00	56.11	56.23
Zinc	40.00	42.64	42.57
Tin	1.56	.75	.68
Aluminum	.40	.47	.50
Manganese	.04	.01	.01
Lead		.02	.01

Manganese bronze may be purchased in ingots, which may be melted as needed, or the alloy may be made by the use of one of the formulas in Table V, which gives the percentages of the various metals in the alloy.

Castings of manganese bronze must have large gates, the risers should be kept open as long as possible by churning, and heavy parts that cannot be fed should be chilled.

10. Manganese bronze is liable to develop segregation of the tin and possibly other metals that are supposed to be alloyed with the copper. The development of segregation is not usually apparent on the surface of the casting; but when a casting has been broken, segregation is indicated by yellow or orange-colored spots. The size and number of these spots indicate the extent of the segregation. Castings in which segregation has developed are, of course, weaker than would have been the case if the metals had alloyed properly.

11. The cause of segregation is not clearly understood, but experiments have shown that its extent may be reduced by the use of large feed-heads and by pouring the metal at a suitable temperature, which should not be too near the freezing point, as the metal will set before the casting can be properly fed. The best pouring temperature for the bronzes given in Table V was found, by the experiments just referred to, to be about 2,000° or 2,100° F. The size and shape of the casting might, however, make it advisable to pour either hotter or colder than at the temperatures given. When mixing the metal for manganese-bronze castings, it is customary to use two-thirds ingot metal and one-third scrap consisting of sprues, gates, and similar remelted material.

TABLE VI

SILICON BRONZE

Metal	Formula No. 1 Per Cent.	Formula No. 2 Per Cent.
Copper ..	97.50	94.00
Tin	1.30	2.40
Zinc	1.15	2.35
Silicon ...	.05	1.25

12. Silicon Bronze.—The strength of bronze may be increased by the addition of silicon; but if the silicon exceeds 5 per cent., the alloy is made brittle. The composition of silicon bronze may be about as given by the percentages in Table VI.

Ferrosilicon should not be used in silicon bronze, as iron injures the alloy. If silicon copper is used, proper allowance should be made for the copper that is added with the silicon.

TABLE VII

TOBIN BRONZES

Metal	Formula No. 1 Per Cent.	Formula No. 2 Per Cent.	Formula No. 3 Per Cent.	Formula No. 4 Per Cent.	Formula No. 5 Per Cent.
Copper	61.2	59.0	62.0	58.2	59.00
Zinc	37.7	38.8	37.0	39.5	38.53
Tin	1.1	2.2	1.0	2.3	2.16
Lead					.31

13. Tobin Bronze.—The percentages of the metals in Tobin bronze are about as given in Table VII. These alloys may be deoxidized by poling or by the use of one of the deoxidizers, such as magnesium, of which about .05 per cent. should be sufficient.

ALUMINUM ALLOYS

14. Aluminum-Copper Alloys.—Aluminum-alloy castings are light and strong, are easy to cast, and resist corrosion well, which qualities, coupled with the pleasing appearance of the white metal, make them exceedingly popular. The most commonly used hardeners for aluminum are copper, silicon, zinc, and manganese, although nickel and magnesium are used to some extent. The cost of aluminum alloys is comparatively high, and they are therefore only used when high strength, light weight, and resistance to corrosion are essential.

The most popular aluminum alloy in the casting industry is that composed of 92 per cent. of aluminum and 8 per cent. of copper. This alloy is commonly known in the trade as *number 12.* The ductility of this alloy is not high, but castings made from it have good resistance to shock and are widely used in motor-car construction. It casts easily and machines well. For commercial use, it may contain not over .2 per cent. of zinc and not over 1.5 per cent. of silicon, iron, manganese, and tin.

Alloys containing more than 8 per cent. of copper are harder and denser but more brittle. An alloy containing 4 per cent. of copper has a tensile strength of 28,000 pounds per square inch and an elongation of 5.5 per cent. in 2 inches when heat-treated.

15. Aluminum-Zinc Alloys.—Aluminum-zinc alloys are much used because zinc is a cheaper metal. These alloys when properly cast produce sharp sound castings. Proper casting conditions, however, are not easy to maintain, and the scrap is likely to be high. The zinc tends to volatilize rapidly and it is hard to maintain an alloy of uniform composition. An alloy of two-thirds aluminum and one-third zinc is commonly used where strong, rigid castings of thin section are required. This alloy has a comparatively low shrinkage. An alloy composed of 82 per cent. of aluminum, 15 per cent. of zinc, and 3 per cent. of copper is sometimes used where resistance to vibration is not of great importance and where good machining qualities are desired.

16. Aluminum-Silicon Alloys.—The use of aluminum-silicon alloys is of comparativly recent development. Iron is exceedingly detrimental to these alloys, and it should be kept at a minimum. Aluminum-silicon alloys possess excellent casting characteristics. They remain fluid at low temperatures and have a low shrinkage on cooling. They may be used to produce intricate castings, and are very resistant to corrosion, but are not so easy to machine as are other aluminum alloys. One alloy that is commonly used contains 11 per cent. of silicon together with small amounts of manganese, copper, and zinc. The iron content must not exceed .8 per cent.

17. The main reason why aluminum-silicon alloys are not used more for engineering purposes is that they have a very low elastic limit. Thus, while their strength compares favorably with several of the other aluminum alloys, they are subject to permanent deformation at comparatively light loads. The physical characteristics of aluminum-silicon alloys are somewhat improved by the addition of a small amount of sodium, usually about .05 per cent. The sodium serves to modify the grain structure, changing it from a coarse grain to a comparatively fine grain.

18. Aluminum-Manganese Alloys.—An alloy containing 2 per cent. of manganese is sometimes used for castings. It possesses good mechanical properties, but has a high shrinkage. It is fairly difficult to cast and must be poured at low temperatures. The use of chills and risers is essential with this alloy. Sand castings made of this alloy are very much improved as to physical characteristics by drop forging. Where the number of castings made is great enough to justify the cost of making a die, the casting may be made slightly oversize and brought to size by cold drop forging.

19. Aluminum-Magnesium Alloy.—Magnalium is an alloy of aluminum and magnesium. Alloys containing much magnesium tend to dross badly and burn in the mold, which results in black-looking castings. Otherwise such alloys show very fair properties. An alloy of 92 per cent. of aluminum and 8 per cent. of magnesium has a shrinkage of about $\frac{3}{16}$ inch per foot.

20. Duralumin.—This casting alloy is used where high tensile strength, ductility, and light weight are essential, as in aircraft construction. By heat-treating, its strength and ductility are increased, and heat-treated castings can be used for high-speed rotating parts. The heat-treating consists of heating to 950° F. for 4 hours and quenching in boiling water. The castings then are reheated to 400° for 1 hour. Sometimes the castings are cooled in air from 950° F. and then reheated to 400°. This gives a lower strength than the first method, but causes less warping of thin castings. The composition of duralumin is as follows: Copper 3.5 to 5.5 per cent., manganese .4 to 1.00 per cent., magnesium .3 to .75 per cent., and the balance aluminum. It has a shrinkage of ⅓ inch per foot and a tensile strength of from 55,000 to 72,000 pounds or more.

TABLE VIII

COMMERCIAL ALUMINUM ALLOYS FOR PERMANENT-MOLD CASTINGS

No.	Aluminum Per Cent.	Copper Per Cent.	Silicon Per Cent.	Nickel Per Cent.	Magnesium Per Cent.
1	95	5			
2	92	8			
3	90	10			
4	88	12			
5	95		5		
6	90		10		
7	87		13		
8	90	4	6		
9	92	3	5		
10	94	4	2		
11	94	5		1	
12	92	6		2	
13	90	4	2	4	
14	92	4	2	2	
15	94	4	1	1	
16	92.5	4		2	1.5
17	89.7	10			.3
No.	Aluminum Per. Cent.	Iron Per. Cent.	Silicon Per. Cent.	Tin Per Cent.	
18	92	1	5	2	

21. Aluminum Alloys for Permanent-Mold Castings. Aluminum-alloy castings may be made in permanent molds if the casting is not too large or intricate or too thin, and where soundness and strength are important factors. Permanent-mold castings are well adapted to heat treatment, since their composition is very uniform. When such castings are made in quantities, the high initial cost of the mold is soon offset by the lower cost of the resultant castings. Aluminum-alloy castings made in permanent molds include automotive parts, bearings, cooking utensils, distributors, electric-fan parts, hardware, instrument panels, knife handles, pistons, and radio parts. In general, the permanent-mold process may be applied when the quantity warrants the initial expense, when the castings must be strong, when the coring is not too intricate, and the castings must machine well and be free from small surface defects.

22. The main characteristic of the aluminum alloys which are used in the permanent-mold casting process is low contraction on freezing so as to minimize cracking. A number of aluminum alloys that have been successfully cast in permanent molds are given in Table VIII. Other alloys consisting mainly of lead and tin have also been cast successfully in permanent molds. These castings are used where strength is not essential and where the whiteness of the metal will improve the appearance of the finished product. Such castings provide a pleasing contrast when used with brass castings, as, for example, in case of brackets and indicators on brass water meters.

NICKEL ALLOYS

23. German Silver.—German silver is an alloy of nickel, copper, and zinc that is commonly used when the part is to be nickel or silver plated. Some German-silver alloys contain other metals to give the alloy some special properties.

A German silver of a white color is frequently desirable when the parts that are made of it are to be nickel or silver plated. When the plating has worn off in spots, a metal of this kind is more nearly the color of the plating and is therefore not so apparent as a darker-colored metal would be. An alloy of this kind, known as *aluminum silver,* much used for the parts of typewriters, has the following composition:

	Per Cent.
Copper	57
Nickel	20
Zinc	20
Aluminum	3

24. In order to make the aluminum-silver alloy, the metals are best alloyed in pairs and the two alloys thus formed then melted together. The aluminum should first be melted, the zinc added to it, and the aluminum-zinc alloy thus formed, then cast into ingots. The nickel and copper should then be melted together under a covering of charcoal, about 2 pounds of borax per 100 pounds of metal being added as a flux. After the nickel is all melted, the aluminum-zinc alloy may be added, the metal being stirred constantly. Before adding the aluminum-zinc, however, it is well to lower the temperature of the copper-nickel alloy as much as possible in order to avoid volatilizing the zinc. The best results are obtained by pouring this alloy into ingots and remelting when castings are to be made. When remelting the alloy preparatory to casting, it may be thoroughly deoxidized by the addition of from 1½ to 16 ounces of magnesium or manganese per 100 pounds of the alloy.

25. A nickel alloy that is used extensively in the manufacture of saddlery hardware for parts, such as bits, that must be excessively hard, has the following composition:

	Per Cent.
Copper	65.00
Nickel	32.25
Aluminum	2.75

Articles made of this alloy should be plated like other nickel alloys, as it will tarnish in time.

The nickel-copper alloy having the following composition is used as a bearing metal:

	PER CENT.
Copper	56.0
Nickel	33.8
Tin	8.7
Lead	1.5

26. Monel Metal.—Monel metal is an alloy of nickel, copper, and iron. There is a monel-metal ore from which the various metals are separated with difficulty and the metal is therefore used in its natural state after being refined. The specific gravity of monel metal is 8.87, and it weighs 5.109 ounces per cubic inch, or 553 pounds per cubic foot. Monel metal melts at a temperature of nearly 2,500° F. and its shrinkage is $\frac{1}{4}$ inch per foot.

Monel metal is used especially for castings that must resist corrosion, for which purpose the natural alloy is said to be better than an artificial one of the same composition. The reason for this difference is not yet apparent.

The natural monel metal is quite uniform in composition, which is about as follows:

	PER CENT.
Nickel	70.0
Copper	28.5
Iron	1.5
Total	100.0

On account of its high melting temperature, monel metal is a difficult metal to melt with an ordinary brass-foundry equipment. It is usually melted in clay-lined graphite crucibles, in gas- or oil-fired furnaces. Clay-lined crucibles are necessary because nickel will take carbon from an unlined crucible, thus injuring both the crucible and the metal. For this same reason, a charcoal covering should not be used over monel metal. A flux of borax or of lime and fluorspar may, however, be used.

Monel metal may be cast in green-sand molds, but they should be skin dried and the inside smoked with resin or coal tar.

BEARING METALS

27. Babbitt.—Babbitt is the name given to a number of soft metal alloys that are used chiefly for the lining of bearings and similar service. Babbitts are of three classes, called, respectively, *tin babbitts, zinc babbitts,* and *lead babbitts.* Tin babbitts are those in which tin is the chief constituent. Zinc is the chief metal in zinc babbitts, and lead is in excess in lead babbitts.

28. Tin Babbitts.—Tin babbitts are sometimes called *genuine babbitts,* though this must not be understood to mean that they are necessarily any better than any other babbitts. Tin babbitt is usually composed of tin, antimony, and copper, though lead may be added in small quantities to increase the compressive strength of the metal and to improve its antifriction qualities. A satisfactory tin babbitt that is largely used is made by preparing an alloy called *hardener* and then mixing 1 part of the hardener with 2 parts of tin. The composition of the hardener is:

	PER CENT.
Tin	83.3
Copper	5.6
Antimony	11.1

The copper should be cut in small pieces and it should be melted under charcoal. The antimony and tin are then added slowly.

All babbitt metal must be mixed thoroughly; some users therefore specify that babbitt shall not be mixed in lots weighing more than a certain amount, say 20 pounds; other users specify that babbitt must be melted at least six times before being delivered. In any case, care must be taken not to overheat the metal.

29. A babbitt that is usually known in the United States as *Government standard babbitt* is somewhat softer than the babbitt just described. It is also more fluid when melted, and linings made of it may therefore be made thinner than when other babbitt is used. The composition of Government standard babbitt is:

	Per Cent.
Tin	88.3
Antimony	7.8
Copper	3.9

The following babbitt is used in the bearings of passenger and freight cars and of high-speed locomotives. It is strong, is not easily squeezed out of the bearings, and is therefore especially well suited to bearings that are subjected to high pressures. The composition of this babbitt is:

	Per Cent.
Tin	83
Antimony	9
Copper	8

30. Zinc Babbitts.—Zinc babbitts are characterized by their strength and toughness. Their wearing qualities are good and they are good antifriction metals. They melt at a high temperature and are sluggish when melted. For this reason the linings that are to be made of this kind of metal must be thick, in order that the babbitt may run into them properly.

The following babbitt has the characteristics of a zinc babbitt, although it contains more tin than zinc and might therefore be classed as a tin babbitt. Tin has the tendency to make the babbitt more fluid. This babbitt is used for the lining of marine bearings. Its composition is:

	Per Cent.
Zinc	34
Tin	64
Copper	2

Other zinc babbitts have the composition given in Table IX.

31. Lead Babbitts.—Lead babbitts are used more extensively than any of the others, because of their low cost and the small amount of friction produced by them. Antimony lead, containing 13 per cent. of antimony, is extensively used in freight-car journals. This alloy is very fluid when melted; it is moderately tough and hard. An essential point in this alloy is that the metals of which it is composed shall be as pure as possible, and some founders specify that only new metal may be used. For use in the bearings of steam engines, electrical machinery, etc. the composition of this babbitt may be changed to 20 per cent. of antimony and 80 per cent. of lead, and for bearings with heavy pressure, the amount of antimony may be still further increased to 30 per cent. with a corresponding reduction in the quantity of lead.

TABLE IX

ZINC BABBITTS

Babbitts	Zinc Per Cent.	Copper Per Cent.	Lead Per Cent.	Tin Per Cent.
Babbitt A	79.0	5.0		16.0
Babbitt B	80.3	6.4	6.4	6.9

What is said to be the best lead babbitt, is composed of lead, antimony, and tin. The composition is:

	Per Cent.
Lead	80
Antimony	15
Tin	5

The tin in this babbitt not only makes it harder than any of the antimony-lead babbitts, but it increases the fluidity of the babbitt when it is melted.

32. Hardware babbitts are made in four grades, which are designated as numbers 1, 2, 3, and 4. The percentages of the materials in each are about as is given in Table X.

SPECIAL ALLOYS

33. Die-Casting Alloys.—Castings are sometimes made by forcing the molten metal under pressure into steel molds. Castings made in this way are called *die castings*. The making of these castings does not usually come within the scope of the brass foundryman's work; but he is sometimes called on to mix the alloys with which die castings are made.

Die-casting alloys are usually white metals, several of the babbitts being used, and in some cases white brass or white bronze is used. Lead babbitts are of very little use for die castings, because they lack both strength and ductility. In this respect some of the zinc-base alloys are preferable, since they are as strong or stronger than gray iron; they are, however, lacking in ductility. A die-casting alloy that contains zinc must also have aluminum, because the zinc tends to separate out and to galvanize the inside of the mold. When the mold becomes galvanized, the casting will stick fast, so that it cannot be removed from the mold, and both the mold and the casting are worthless. Zinc-base alloys may, however, be finished by plating with brass or nickel. Tin-base alloys are used to a considerable extent in the automobile industry for the manufacture of die-cast bearings, and they are also used in the manufacture of parts for soda-fountain pumps. The composition of some die-casting alloys is given in Table XI.

TABLE X

COMPOSITION OF HARDWARE BABBITTS

Babbitt	Lead Per Cent.	Antimony Per Cent.	Arsenic Per Cent.	Tin Per Cent.
Babbitt No. 1 ..	62.4	16.0	.8	20.8
Babbitt No. 2 ..	68.6	17.6	.9	12.9
Babbitt No. 3 ..	74.1	19.0	.9	6.0
Babbitt No. 4 ..	78.0	20.0	1.0	1.0

Aluminum alloys may be die-cast in a machine. The metal is forced into the die by air pressure. Practically any aluminum alloy that has a low shrinkage may be die-cast in this way.

34. Type Metals.—There are a number of type-metal alloys, the simplest being an alloy of lead and antimony. They are used for many small castings as well as for the manu-

TABLE XI

DIE-CASTING ALLOYS

No.	Zinc Per Cent.	Tin Per Cent.	Copper Per Cent.	Lead Per Cent.	Cadmium Per Cent.	Phosphor-Tin Per Cent.	Antimony Per Cent.	Aluminum Per Cent.	Remarks
1	5.00	2.00		84			9		
2	83.00	3.00	10.00	2	1	1			White brass
3	85.00		10.00					5.00	
4	88.00		4.00					8.00	
5	73.75	14.75	5.25					6.25	
6		78.00	8.00		1	4	9		White bronze
7		80.00	3.00		1	4	12		
8		82.00	2.00				16		
9	34.00	64.00	2.00						

facture of type. Some type metals are made of tin and antimony and sometimes other metals are added to increase the fluidity of the metal when melted or to give it other desirable properties. In general, the more antimony the type metal contains, the harder the alloy. Table XII gives the composition of some type metals.

TABLE XII

TYPE METAL ALLOYS

No.	Antimony Per Cent.	Lead Per Cent.	Tin Per Cent.	Bismuth Per Cent.	Copper Per Cent.	Nickel Per Cent.
1	2.5	60	37.5			
2	10.0	90				
3	15.0	77		8		
4	17.0	83				
5	18.0	64		18		
6	18.0	60	11.0	1	5	5
7	20.0	80				
8	24.0	71			5	
9	25.0		75.0			

35. Britannia Metals.—Britannia metal is similar to type metal; but it is composed of tin, instead of lead, hardened with antimony. Other metals are sometimes added in small quantities to increase the fluidity, lower the melting point, or supply other desirable properties. Table XIII gives the composition of some kinds of Britannia metal.

36. Impurities in Non-Ferrous Alloys.—Impurities in non-ferrous alloys may be introduced in various ways. One source by which the contamination may take place is the scrap which is often melted with the new metals in forming the alloy. Another way by which undesirable elements may enter the alloy is by melting alloys of dissimilar compositions in the same furnace instead of in separate furnaces. Iron is the most common impurity met with in non-ferrous alloys. Iron is oxidizing and causes a sluggish drossy metal. Castings poured from a brass alloy containing iron are much darker than would otherwise be the case. Iron oxidizes readily and may be skimmed off. Phosphorus, however, combines with iron and prevents oxidization. A common source of contamination from iron lies in the iron hooks which are used for skimming. Brass attacks iron readily, and to prevent this, all iron skimmers should be coated with a clay wash. The higher the carbon content of the iron skimmer, the more susceptible it is to attack and therefore Norway iron, wrought iron, or mild steel skimmers are used. Brass will attack iron to such an extent that parts of the skimmers will drop off into the metal if left in it too long, although the temperature of the brass may be considerably below the melting point of the iron. Therefore, care should be taken not to immerse the skimming rod in the molten metal for too long a time, and any iron that may fall into the ladle should be promptly removed. Where it is especially desired that the alloy be free from iron, skimming should be done with a graphite rod or one of dry, hard wood.

TABLE XIII

BRITANNIA METAL ALLOYS

No.	Antimony Per Cent.	Tin Per Cent.	Copper Per Cent.	Bismuth Per Cent.	Zinc Per Cent.
1	7.5	91	1.50		
2	7.5	85	2.25	2.25	3
3	9.0	91			
4	10.0	85	1.00	1.00	3
5	10.0	86	1		3

37. Aluminum is probably the next most common and most harmful impurity in brass. It is particularly detrimental to castings that must withstand pressure. Aluminum oxidizes readily, but it does not separate out as does iron and hence cannot be skimmed off. Thus the aluminum oxide is carried into the finished casting and tends to make it porous. Antimony behaves much the same as aluminum, but it is not encountered so often. The way in which it is most commonly introduced into brass is through remelting old bearings that have a soft metal lining containing antimony.

BRASS-MOLDING PRACTICE

MATERIALS FOR BRASS MOLDS

38. Shrinkage of Non-Ferrous Alloys.—All alloys used in the brass foundry shrink a good deal on cooling; but the amount of shrinkage varies. Allowance for this shrinkage must be made in the pattern and also in the manner of making the mold. Table XIV gives the shrinkage per foot that may be expected in various metals and alloys.

TABLE XIV

SHRINKAGE ALLOWANCES

Material	Shrinkage per Foot Inch
Brass	$\frac{3}{16}$
Manganese bronze, large castings	$\frac{1}{8}$
Manganese bronze, small castings	$\frac{3}{16}$
Copper, pure	$\frac{1}{4}$
Tin	$\frac{1}{4}$
Lead	$\frac{5}{16}$
Zinc	$\frac{5}{16}$
Aluminum, pure	$\frac{1}{4}$
Aluminum 93 per cent., copper 7 per cent.	$\frac{3}{16}$
Magnalium, 8 per cent. magnesium	$\frac{1}{8}$
Monel metal	$\frac{1}{4}$
Babbitt	$\frac{5}{64}$
Parson's white brass	$\frac{3}{64}$

If the casting from a wooden pattern is to be used as a pattern with which to make molds, the first pattern should have a shrinkage allowance equal to the sum of that for the metal pattern and that for the final casting stated in Table XIV.

39. Cores for Brass and Alloys.—Cores for use with nonferrous alloys differ from those used in making iron castings in two main respects. First, they are not vented as heavily as cores for iron work; and, second, they are generally made of finer-grained sand. Cores used in iron foundries are thoroughly vented, and all except the most simple must stand the smoking test; that is, smoke blown through one vent opening must pass through and out of all other vent openings. The molds themselves are not generally vented. The opposite is true of brass-foundry practice. The molds are heavily vented by one or more of the methods described below. The cores, unless exceptionally intricate, are vented with a few jabs of a wire, and no particular effort is further made to keep the vents open. There are, of course, exceptions to this rule when the core is complicated and the casting subject to core blows. Some cores are smoked. Large cores for castings of very thin wall section are often filled in the center with coke to provide for easy escape of gases and to provide a comparatively weak core that will give easily under shrinkage stresses.

40. Core sands commonly contain some clay and silt, and the resulting cores are not of uniform fineness. The grain size may be made more nearly uniform by washing the sand. A stream of water is caused to flow through a container that holds the core sand, and the sand is constantly agitated. Most of the clay and silt is carried away by the exhaust water. Ottawa sands or those of similar composition are commonly used for making small and medium cores for brass castings. River sands such as are often used for large, heavy cores are, of course, already washed. Brass castings are generally used more in conspicuous places without being machined than are iron castings. For this reason and because a core of high permeability is not essential, a fine-grained sand is used in making the cores.

The cores are heavily coated with plumbago where a particularly smooth surface is desired. This coating also prevents the burning in of the core sand on castings that are poured very hot and that are of large sectional area. A comparatively cheap core wash that is satisfactory for a number of purposes may be made up of finely ground anthracite or coke mixed with sandstone and clay. Binders and methods of making cores are similar to those used in iron-foundry practice.

41. Molding Sand for Brass Castings.—The suitability of a molding sand for use in the brass foundry must be judged on the following characteristics: (1) It must not melt or fuse at the temperature of the metal that is to be molded in it. (2) It must have a sufficient bond to hold it together and to enable it to resist the casting strains. (3) It must be fine enough so that the metal will not run in between the grains of sand and yet not so fine that gases cannot escape readily.

When deciding on the fineness of the sand that is to be used, the fluidity of the metal that is to be molded and its tendency to give off gas must be considered. The nature of the castings that are to be made also have a controlling influence. When the castings must have a smooth surface, a fine molding sand must be used. When, however, the mold must be capable of freeing itself of considerable quantities of gas and air, a relatively coarse sand is required.

42. Partings for Brass Molding.—Partings are used between the parts of a mold so that they will not stick together. Burned molding sand is commonly used for this purpose. It should be kept very dry and should be put through a riddle having from 60 to 80 meshes per inch. Burned molding sand is, of course, very cheap, the only expense connected with it being that of the labor necessary to prepare it. Its chief disadvantageous feature is that it will absorb moisture from the green molding sand and hence loses its efficiency as a parting after the mold has been closed for a time. In cases where it is necessary to reopen a mold, it is not satisfactory. Such a condition arises occasionally when a core becomes broken after the mold has been made and another is not available for some hours.

Lycopodium is the best parting for use when the best quality of work is desired. It is too expensive for ordinary work but is commonly used when making cast plate patterns. Lycopodium is composed of the seeds of club moss. The seeds are coated by nature with a thin layer of oily substance, and hence, when used as a parting, they resist moisture well. Commercial partings are made of fine dry siliceous material and are used for the ordinary run of brass-foundry work. Where special imperviousness to moisture is desired, the grains are given a thin coating of commercial waxy material.

43. Partings on Metal Patterns.—Metal patterns sometimes give trouble, especially in cold weather, by collecting moisture, that is, by what is commonly called *sweating*. The moisture on the pattern makes the sand stick so that when the pattern is drawn, an imperfect mold is left. To prevent this, coating the surface of the pattern with kerosene has been tried but has not proved entirely successful. Some molding machines are provided with one or more gas burners to keep the pattern warm and prevent the collecting of water. Care must be exercised, however, to see that the pattern does not become so hot as to dry or burn the sand in the mold. Another way of preventing sweating is to cover the pattern with a coating of Brazil wax.

44. Mold Facings for Brass and Alloys.—Facings are used in molds to give the surface of the mold an open, or porous, structure that will allow gas to escape freely, to render the sand in the surface of the mold more refractory and consequently enable it to resist a higher temperature, and to give the castings a smooth surface. It also tends to make the molding sand peel away from the casting readily when shaking out.

A good facing must adhere to the molding sand, must be refractory, must not produce much gas, and must be fine. To test the fineness of any given facing, a weighed amount is brushed over an area of compacted molding sand 5 inches square. The facing is brushed back and forth until no more will adhere to the molding sand. The surplus facing is gathered and weighed, and a good indication of relative fineness is thus obtained. Some of the common facing materials are fine sand, plumbago or black lead, talcum, charcoal, sea coal, coke, flour, and lycopodium.

45. Sometimes a little sand sifted finer than usual is the only facing that is needed to give the required smoothness of surface. Plumbago, or black lead, gives a smooth surface, makes the sand more refractory, and tends to prevent the metal from washing away the sand over which it flows. Talcum powder, which is soapstone ground very fine, serves much the same purpose as plumbago. Lycopodium is very fine and burns easily, after which the surface of the mold is left somewhat porous so that the gases escape more readily than they would otherwise. Plumbago, talcum, and lycopodium are especially adapted for use when the pattern is to be printed back, as they keep the sand from sticking and drawing away the next time the pattern is lifted. Charcoal, sea coal, and coke are also used to make the facing sand of the mold porous. These materials are ground and sifted to the fineness of flour. This process is called bolting. Sea coal for brass founding is a good grade of anthracite coal that has been ground and bolted. It is mixed with the molding sand in varying proportions, depending on the conditions under which it is to be used. The quantity of sea coal should vary with the degree of porosity that is to be given to the mold; the more porous the mold is to be, the larger the quantity of sea coal that should be used. It is, however, seldom advisable to use less than five times as much sand as sea coal, and the proper proportion may be as high as as 25 parts of sand to 1 part of coal.

46. Bituminous sea coal, as used in molds for heavy gray-iron castings, gives off considerable gas at high temperatures, and for this reason, a facing made of ground anthracite coal is to be preferred for brass founding. The best facing of all is flake graphite, but its high cost prevents common use. Flake graphite is sometimes cheapened by mixing it with clay or soapstone, but the quality of the resulting mixture is lessened. Two different facings are sometimes used together. A facing made of some material containing clay is first applied, after which a layer of powdered charcoal is dusted on. The first facing tends to hold the second.

MOLDS FOR BRASS CASTINGS

47. Ramming and Venting the Mold.—The correct ramming of a brass mold is of great importance, not only on account of the shrinkage strains that may be produced in a casting by a mold that has been rammed too hard, but for other reasons that will now be explained. The air in the mold and the gases formed in the metal must escape from the molds, or the castings will be defective. These gases are usually allowed to escape through the sand of the mold, which must be porous enough for that purpose. On the other hand, if the mold is not rammed hard enough, the metal, when flowing into the molds, will wash channels in the sand and the castings will thus be made faulty. A coarse sand can be rammed harder than a fine one and still be sufficiently porous to rid the mold of gas. When, however, the coarsest sand that will give the castings the required smoothness of surface is not porous enough to rid the mold of gas, the mold must be vented.

48. Molds are vented to facilitate the escape of the air that is in the mold and of gases that may be contained in or generated by the hot metal. When the porosity of the mold will not provide all the necessary venting, a few holes may be made with a wire. In case a pan-shaped casting is to be made upside down, the bottom as well as the top of the mold must be vented. The drag may sometimes be vented before the mold is closed by piercing holes to the bottom of the mold with a vent wire. If sufficient venting cannot be provided in this way, strings leading from the space below the pattern to the top of the mold may be laid in the sand and drawn when the mold is all rammed up.

49. Molds that must be vented freely are vented by jabbing the cope, before it is drawn, with a stiff wire. From fifteen to twenty-five jabs are required for a complicated mold made in an 11″×16″ flask. Long thin sections projecting into the cope are vented after the cope is drawn by passing a stiff wire from the top of the projection on the inside of the cope through to the outside surface, the wire being pulled all the way through. Thin flat castings are vented by scratching the parting surface of the mold in either the cope or the drag before the mold is closed. The scratches are made from the pattern impression out to the edge of the flask and may be made with a slick. Such vents are called *drawn vents*.

50. Skin-Dried Molds.—When a particularly fine quality of brass or alloy casting is desired, the mold is skin dried. The sand of which the mold is made, or at least that part of it in which the pattern impression is made, is mixed with molasses or starch binders similar to those used in making cores. A gas flame is then played over the surface of the finished mold until all moisture is driven from it. The dry, hard surface of the mold yields castings that are particularly smooth and fine-appearing.

51. Gating Molds for Brass.—The gates in the mold must be large enough to allow the metal to run freely to all parts of the mold. Gates for brass castings must be larger than if the same castings were to be made of iron, for brass does not flow so freely as iron and is poured at lower temperatures. Machine patterns that have been gated for use with iron must be regated if they are to be used for brass work. The amount of gating required depends on the weight and size of the casting. The larger the casting the larger and longer are the gates required. For a given weight, the greater the area of the casting, the greater will be the amount of gating required to run metal to all parts of the casting. Similarly, the smaller the area for a given weight, the less is the gating required until at a certain point the sprue or pouring gate is all that is needed. As the area decreases beyond that point, the casting becomes heavy and must be fed during cooling to offset the effects of shrinkage. This feeding is accomplished by the addition of one or more risers, the number depending on the chunkiness of the casting.

52. The nature of the alloy and the permissible pouring temperature also affect the gating. Some alloys flow much more freely than do others, and they may be poured at a much higher temperature. Such alloys permit the use of very thin gates. In all cases, the gate should be as thin as other conditions permit at the point where it joins the casting to facilitate its subsequent removal during cleaning. If it is made sufficiently thin, the gates may be broken off by hand. For a given gate area, the gate is easier to break off if it is thin and flat than if it is round. Some alloys are very difficult to pour. In this case, the mold is often gated in both the cope and the drag. In general, gates should be kept as small as possible, to prevent excess scrap, to reduce cleaning labor, and to reduce the amount of metal that must be melted to pour a given casting.

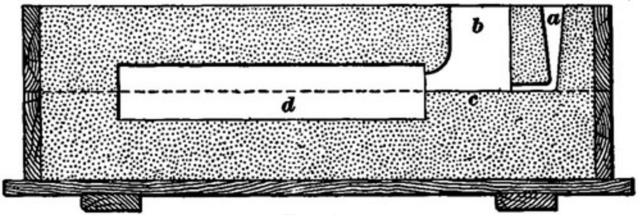


FIG. 1

53. Most castings are gated so that pouring may be done through a pouring gate located at the end or the side of the mold. For thin light castings of circular shape, however, the pouring gate is located in the center of the mold. This permits the metal to flow out to all parts of the mold in a uniform manner. Long narrow castings of thin section must be poured from both ends at once, the metal meeting at some point near the middle of the casting. This necessitates a pouring gate at either end of the mold, and, of course, two pouring crews at the time of pouring.

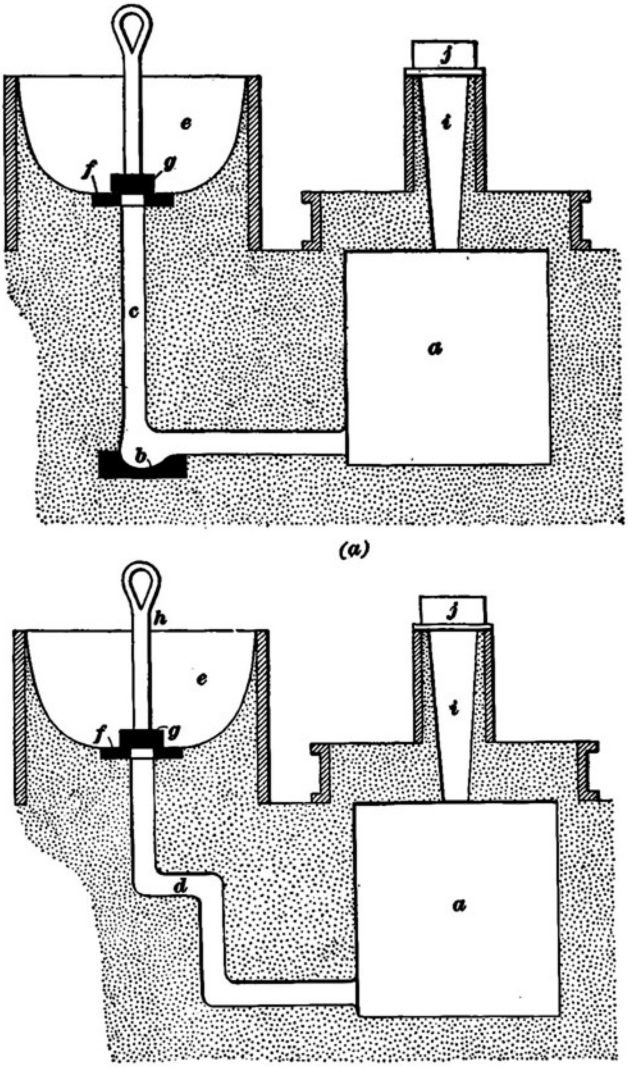
54. An arrangement of a skimming gate and riser combined is shown in Fig. 1. The pouring is done through the gate *a*, which is made narrower at the bottom than at the top. On account of this narrowing of the gate, the metal will not run out as fast as it is poured in and the dross, which floats, is retained in the pouring gate, which is therefore also a skimming gate. A large riser or feeding gate *b* is placed on the runner *c* that leads to the casting *d*.

55. Feeding Molds.—In the making of molds for large brass castings, provision must be made for properly feeding the casting, and the gates must be so arranged that the casting can be poured quickly and yet not permit sand to be washed from the gates into the castings. In Fig. 2 are shown two arrangements of gates and the application of a pouring basin and a riser to a large casting *a*. If the pouring gate is long, the metal, when it strikes the bottom, will wash sand loose and carry it into the mold. In order to prevent this, a graphite plate *b*, view (*a*), is placed at the bottom of the pouring gate *c*. Another way of preventing the washing of the gate is to break the fall of the metal by putting a bend in the pouring gate, as is shown at *d* in view (*b*).

56. As brass castings must usually be poured very rapidly, large pouring basins, such as is shown at *e*, Fig. 2, are desirable. A graphite plate *f* having a hole in the center is placed in the bottom of the pouring basin and the hole in *f* is closed by a graphite plate *g* until the metal is to be run into the mold. The stopper plate *g* may be lifted by the handle *h*, which is provided for that purpose.

The top of the riser or feed-head *i* should be at least as high as the top of the pouring basin, so that metal will never run out of the top of the riser. It should be kept closed by a weight *j* as much as possible, so as to prevent the loss of heat. Should the pouring gate solidify before the casting has set, pouring may be continued through the riser, which may be churned, if necessary, to keep it open, by using a thoroughly dried, wooden feeding rod.

57. Pouring Brass Molds.—Since brass does not pour as easily as iron, more care must be used in pouring to keep the scrap down to a minimum. For a number of alloys, the metal must be forced rather than poured into the mold; that is, pouring must be very rapid and the pouring gate must be kept full. For light thin castings more metal is poured than can actually flow through the sprue, considerable spillage being the result, but the sprue must be kept completely full. Large castings may be poured more slowly. When iron molds are used, the



(a)

(b)

FIG. 2

pouring must be very slow and steady, and the mold should be kept filled at the top during the initial cooling and shrinkage.

58. Aluminum-Alloy-Molding Practice.—There is little difference between aluminum-alloy-molding practice and brass-molding practice. Both molds and cores must, of course, be properly vented to permit the escape of gases. In general, a finer molding sand may be safely used with aluminum than with brass, thus giving a better appearing surface on the finished casting. Chills are quite commonly used to prevent shrinkage cracks. For small bosses on very thin-walled castings, small flat-headed copper rivets make excellent chills. Where larger sections must be chilled, copper or iron blocks of sufficient size are commonly employed. Usually it is not necessary to sand-blast aluminum-alloy castings during cleaning, as practically no molding or core sand will adhere. For large and very thin-walled castings it is better to remove the excess metal left after sawing the gates, by filing it off rather than by grinding, as the grinding shocks are likely to break the casting. Aluminum will acquire a satiny finish if buffed on a buffing wheel.

59. Permanent, or Long-Life, Molds.—A mold is generally made up and completely destroyed for each casting or group of castings made. A considerable saving in time, labor, and material handled could be effected, therefore, by the use of molds that can be used over and over again. Durable molds are divided in two classes, the *semipermanent mold* and the *long-life,* or *permanent, mold.*

60. A semipermanent mold may be made up of firebrick built up and bolted together. The metal may be poured directly on the bricks if the surface is later to be finished or the bricks may be coated lightly with green sand. In some processes, the drag is made permanently and the copes rammed up separately for each casting, whereas in others both the cope and the drag are made to last. Some molds are made of materials which are similar to those used for making firebrick and are burned and treated in the same way. Such molds as those just described may be made to last for from 100 to over 1,000 castings.

61. Castings are made in long-life molds by pouring liquid metal into a metal mold, the metal entering the mold solely under the force of gravity. The process is therefore different from die-casting, in which the metal is forced into the mold under pressure. Usually the mold is made of cast iron. In casting, the metal is poured directly into the heated mold. During cooling, the casting is fed by a gate and by one or more risers. As soon as the shell of the casting has become strong enough to be handled the mold is opened and the casting removed. Generally it is necessary to heat the mold only for the first casting, as the heat from the pouring process keeps the mold hot thereafter. If the cores used are simple and of such nature that they may be withdrawn from the casting, they may be made of steel or cast iron, alloy steel being commonly used. Intricate cores may be made of sand, a new core being used for each casting. Sound and strong castings may be made in long-life molds, the quality being as good as that of castings made in sand molds, or by die-casting, and in many cases they are better.

Long-life mold castings cool at a more rapid rate than sand castings, thus producing a smaller grain size. On the other hand, they do not cool as rapidly as die castings, and hence there is more chance for dissolved gases to escape. The castings machine well, and the machining allowance is less than for sand castings, because of the uniformity of the castings produced.

62. Pouring Temperatures.—The temperature at which the metal is poured when making brass castings has a decided effect on the finished castings. Pouring the metal too hot may cause swelling or sand burning on the casting and there is danger of included gases or oxides. On the other hand, pouring dull metal causes faint runs, particularly on light, intricate work. Castings which must withstand pressure must not be poured too hot, as excessive shrinkage will cause faulty castings, and since such castings are often thin-walled, the danger of faint runs from dull metal is exceptionally great. In general, the pouring of metal at proper temperatures reduces scrap losses and improves the quality of the finished product. The desirability of pouring at correct temperatures is being realized more and more in good foundry practice. There are two methods in general use for determining the temperature of non-ferrous alloys; first by visual control, and second by electric pyrometers. The first method is the older, dating from the beginning of the founding art, but it is the less accurate and may only be employed with satisfactory results after years of experience.

63. Visual control of the pouring temperature calls for judgment, by sight, of either the color or the viscosity of the metal, or both. All metals tend to become white with rising temperature, but the color on approaching white varies with the individual alloy. No definite rule may be laid down, and therefore temperature judgment by color must be based on experience with the particular alloy involved. Considering some of the more common alloys, copper shows a dull red at low temperatures, changing to a bluish white as the temperature increases. Aluminum progresses from white to red and then to orange white. An alloy of copper 85 parts, tin 5 parts, lead 5 parts, and zinc 5 parts is reddish yellow at low temperatures and becomes a yellowish white with a bluish tint at higher temperatures. An alloy of copper 70 parts and zinc 30 parts proceeds from dull yellow to yellowish white, emitting bluish yellowish tints as the zinc volatilizes. These colors vary with the light in which they are viewed, appearing differently in sunlight and shadow.

64. The viscosity of the metal may be determined by sight or feeling, or both. Viscosity varies with the temperature, the metal becoming more viscous with lowered temperatures and more fluid as the temperature increases. If the metal is hot, it looks thinner and its surface lies flatter than when cold. A skimming rod or any solid immersed in the metal meets with less resistance in hot metals. Cold metal has a dull and lifeless look, whereas hot metal appears limpid. If metal is cold when pouring, it tends to solidify on the lip of the ladle in thin sheets or streamers. Metals that do not contain phosphorus tend to form an oxide film on the surface, giving a lifeless appearance to the metal, which may, however, be hot enough. This film should be kept dispersed with a skimming rod when temperature is being judged. Conversely, the addition of phosphorus makes the metal appear hotter than it really is. Temperature determination by the use of a pyrometer is fairly accurate and dependable.

CLEANING NON-FERROUS CASTINGS

65. Cleaning Department.—After the castings have been shaken out, all sand and cores are removed and gates, sprues, risers, and fins are knocked off or cut off. A final burnishing or acid bath may or may not be given to the casting to improve its appearance. The cleaning operations involve considerable handling and rehandling of the castings, and modern cleaning equipment is designed to reduce this handling to a minimum. The amount and nature of the cleaning equipment that may be profitably installed in a brass foundry depends on the volume of work cleaned, the nature of the castings, and the composition of the alloys. A small jobbing foundry may operate successfully with a few pieces of general-purpose equipment, whereas the larger or more specialized foundry will find it profitable to install expensive single-purpose machines.

66. Removing Cores and Sand From Non-Ferrous Castings.—The first step in cleaning castings after they have been shaken out is the removal of all cores. The cores are usually soft and may be knocked out with a hammer, gouged out with an iron bar, or removed by air-operated knocking-out machines. Large cores may be quickly broken up with an air-operated chipper. They will then fall out easily when the casting is inverted. Reinforcing wires will fall out with the core unless they are bent, in which case they must be pulled out by hand. Wires, rods, and nails thus obtained are usually collected, the larger ones being used again and the smaller ones sold as scrap iron. Complicated cores on small, weak castings are sometimes "blown" out as follows: The casting is shaken out as soon as it solidifies after pouring and is immediately immersed in water, the steam thus generated serving to blow the weak core to pieces. This water quenching has little or no hardening effect on non-ferrous alloys.

The surface of alloy castings, such as aluminum and manganese bronze, is so smooth that what little sand adheres may be removed with a stiff wire brush. All other castings are cleaned either in a tumbling barrel or in a sand or shot blast.

When brass castings are cleaned in a sandblast, they are loaded onto durable cast-iron trays and pushed on trucks into a small dust-proof room. Sand is shot over them through a hose, an operator directing the blast. The operator may stand in the chamber with the castings, in which case he must wear a dust-proof hood with special respiratory apparatus. In the newer types of sandblast, the operator stands outside the room. The nozzle of the hose is within the chamber, but its direction is controlled from the outside. The castings stand on a turntable, which may be rotated electrically at the will of the operator. The sand used for cleaning is fine, dry sand having sharp, angular grains. The grains become rounded after being used a few times and lose their cleaning power. The daily addition of new sand keeps the sand in effective cleaning condition and also serves to replace sand that is carried out of the sandblast chamber with the castings. Small steel shot is sometimes used in place of sand.

67. Removing Gates, Risers, and Other Excess Metal. If small, chunky castings are shaken out hot, they may often be broken away from the gates by simply knocking them sharply against the floor. This practice is better suited to production molding, in which pouring and shaking-out are continuous. In jobbing work, the nature of the work is so varied that a high percentage of scrap may result from lack of knowledge of the proper time to shake out. In such foundries, some other method of removing gates is more satisfactory. If the casting is made from a free-pouring alloy and if it may be poured at a high temperature, it may often be gated so thinly that the gate can be broken off the casting by hand. On large castings and castings that have heavy gates, the excess metal must be removed by band saws or sprue cutters.

68. The best type of saw blade to use on medium-hard alloys is probably the ordinary band-saw blade commonly used by patternmakers for wood working. This saw will successfully cut copper, aluminum, red brass, and yellow brass. It may be readily resharpened and may be used a number of times. An automatic saw sharpening machine may be installed in the foundry repair shop which will resharpen dull band-saw blades wtih no other attention than loading and unloading. For hard brasses, this type of saw dulls very quickly and a hardened-steel band saw is to be preferred. These saws may be sharpened once or twice by sandblasting, but their cutting life is not long after resharpening. Soft alloys such as are used for bearings will quickly dull any saw. Therefore, it is better to remove excess metal from castings made of such metal with a sprue cutter. This process leaves more excess metal on a casting than does a band saw, but since it is used only for soft alloys, the remaining metal may be easily ground off.

69. Gates are ordinarily cut from large castings by means of an air chipper. Fins and rough spots on castings are also removed this way. Risers may be chipped off or knocked off with a sledge hammer if the riser base is comparatively small. Otherwise they must be cut off on a table saw. The casting is securely clamped to a movable table and is fed into a heavy slow-speed circular saw. Heavy risers are sometimes cut off by an electric arc, if the heat generated by the arc does not affect the quality and strength of the metal in the casting. Large scrap may be cut by the electric arc into sizes suitable for charging into the furnaces. Cutting by any of the means mentioned above is comparatively quick and all cuts should be made as close as possible to the casting to reduce to a minimum the slower operation of grinding.

70. Grinding Non-Ferrous Castings.—Surplus metal that cannot be removed by cutting may be ground off. The surface of the casting is ground smooth where the parting line of the mold is visible, and all rough spots are removed. A carborundum wheel about 2 inches thick is suitable for this purpose. Small slots may be ground out with thinner wheels. Castings that require a very smooth surface may be buffed on a felt buffing wheel.

Special automatic grinding machines have been developed for small work that is made in large quantities. The castings are fed into the machine by a hopper and are automatically ground free of all excess metal. The design of such machines depends on the nature of the casting, and their use is rather limited.

71. Filing, Chipping, Etc.—Excess metal that cannot be removed from brass castings by grinding may be removed by hand on a cleaning bench. The tools used for this purpose are largely cold chisels, hammers, and files. Aluminum castings of thin section are often filed instead of being ground, to avoid danger of breakage. The gates are first cut off on a sprue cutter and then chipped and filed down on the bench. Burned-in cores are also dug out on the bench.

72. Finished Castings.—Castings that must have a particularly good appearance are often resandblasted or tumbled again in the sand barrel after all excess metal has been removed. A burnished appearance may be given to small castings by tumbling them in a water barrel. The castings are placed in the barrel through which clean water flows continually, and are tumbled for one or two hours.

73. Pickling.—Brass castings may be pickled to remove sand, though the object of pickling is more commonly to improve the appearance of the castings. A good pickling solution is made by mixing 1 gallon of commercial sulphuric acid with 10 gallons of water. No advantage is gained by making this solution any stronger, but its action may be hastened by heating the solution to a temperature of about 150° F.

The time during which the pickling action should be continued depends on the casting. If the casting is fairly clean when it is put into the pickle, the action usually need not be continued longer than 30 minutes. When, however, sand is burned fast to the castings, as is sometimes the case with phosphor-bronze, the pickling action may have to be continued as long as 24 hours. Castings that are being pickled should be removed from the acid occasionally and examined to see that the pickling action has not progressed too far.

74. Castings should be washed when they are taken from the pickling bath, in order to remove all of the acid, as any acid remaining on the castings will corrode them and produce discolored spots.

A peculiar matt finish may be produced on brass castings in the following way. The castings are first pickled in a solution composed of 1 part of hydrofluoric acid mixed with 3 parts of water and then washed in clean water. This treatment will remove all sand that may be adhering to them. The castings should then be dipped in a solution made of equal parts of nitric acid and sulphuric acid, to every 5 gallons of which solution 1 tablespoonful of salt has been added, washed in clean water, and dried by dipping in very hot water and swinging. Bright surfaces obtained in this way must be lacquered to prevent them from tarnishing.

75. Two pickling solutions are used for German-silver castings. The first solution is made by mixing 1 part of nitric acid in 12 parts of water and the second solution is composed of equal parts of nitric acid and sulphuric acid. The castings are dipped quickly in the first solution and then in the second; after which, to prevent corrosion, they are rinsed in clean water and carefully dried in sawdust. Care should be exercised that the pickling solutions are not too strong or that the castings are not left in them too long, since in either case a needlessly large amount of metal will be dissolved and wasted.

76. Repairing Non-Ferrous Castings.—Broken or faulty non-ferrous castings may be repaired in various ways. Holes can often be closed by inserting plugs of the same alloy as the castings. Peening with a hammer is used with more or less success. Soldering, brazing, and welding have their uses in repairing castings. In the case of porous aluminum castings, the application of water-glass under pressure followed by washing with cold water and drying has given good results. Boiled linseed oil, bakelite, shellac and varnishes, sulphur, soap, and other liquids are also used for this purpose.

"Burning in" defective spots on castings is sometimes allowed, although it has to be done with great care to avoid cracking the castings, especially if the alloys used are not ductile. The casting is buried in molding sand in such a way that only the spot to be burned in is uncovered. A shallow surface gate is cut to run the metal to the desired spot, and a deep basin is provided for surplus metal. To burn in the spot, metal is poured continuously for about a minute. The hot metal gradually melts the edges around the defective spot. When the pouring is stopped, the metal cools and makes a solid section. In automobile practice, surface defects on aluminum-alloy castings are sometimes eliminated by welding the defective spots by means of a gas torch. A rod consisting of the same material as that of the casting is used to supply the necessary metal to fill the void on the surface.

POLISHING AND PLATING

77. Polishing of Brass.—When brass or other castings are to be plated, the surfaces must be polished or a smooth plate will not be obtainable. The first operation in the polishing of brass is to smooth the surface by filing, scraping, or that went before. The surface is eventually covered with comparatively coarse scratches, which must be removed in order to produce the desired polish. The removal of these scratches is accomplished by a series of polishing operations, each one of which replaces the scratches produced by the previous operation with a set that are a little finer than those that went before. The surface is eventually covered with scratches that are so fine that they cannot be seen with the naked eye.

The following set of polishing operations may be employed: The marks of filing or other smoothing operation are removed by means of a leather wheel covered with coarse emery or pumice stone, followed with rotating brushes that are fed with tallow and fine emery. Then a cloth wheel may be used with crocus or tripoli powder. The polishing powder is finally removed and the casting is washed and dried in sawdust. If a still better polish is desired, the surface may be buffed by a canton-flannel wheel with hard rouge.

78. A fair degree of polish may be obtained on many small castings by means of a tumbling barrel. The castings to be polished are put in the tumbling barrel with an equal volume of water and twice their volume of steel balls. About 4 ounces of a good soap, such as borax or ivory soap, should be dissolved in each pailful of water. The balls should be perfectly smooth and round. They should be of a size suited to the work; the more intricate the detail, the smaller the size that will be required. In any case, the larger the size of the balls, so long as all parts of the castings are reached and the balls are not so heavy as to damage the castings, the cheaper the work, though small balls will do the work faster and better. Sometimes large and small balls must be mixed, in order to get sufficient weight into the barrel to do good polishing. When, however, very delicate castings are being polished by this method, they are sometimes protected from damage by putting pieces of wood and leather into the barrel. The polished castings may be separated from the balls by dumping the contents of the tumbling barrel on a coarse sieve that will allow the balls to fall through, but will retain the castings, from which the pieces of leather and wood may be picked by hand.

79. Plating Brass Castings.—After all machine work has been done, castings are frequently plated in order to improve their appearance or to make them less likely to corrode. Copper, nickel, and silver plating are most commonly used. Copper plating is used either as a protection against corrosion or as a foundation on which nickel or silver plating is to be done. When intended merely as a protection from corrosion, copper plating need not be polished. If used as the foundation for a plating of either nickel or silver, the copper plate must be polished, and the better this polish the better will be the finish of the nickel or silver plate. The nickel or silver plate may have any desired degree of polish.

After a surface that is to be plated has been polished, it must be washed until it is free from all grease, as plating will not adhere to a greasy surface. If the hand touches the surface that is to be plated, grease enough to cause the plate to come loose is apt to be deposited. Articles to be plated are therefore usually suspended on copper wires before they are cleaned. After being polished and washed they may be dipped in a solution of 8 ounces of potassium cyanide, in 1 gallon of water, to complete the cleaning. The article to be plated is then attached to the negative side of an electric circuit and is suspended in a tank, containing a plating solution and a piece of metal, called an anode, which is attached to the positive side of the electric circuit.

Tanks that hold the plating solutions are made of pine or cypress that is free from knots and flaws. Nickel-plating tanks should be lined with burlap fastened on with copper nails and then coated with asphaltum and pitch. For copper and silver plating, the burlap need not be used, but the tank is lined with paraffin.

80. Plating Solutions.—Numerous plating solutions have been used but those given here are among the most common. For copper plating, either one of the two following solutions may be used: (1) The first solution is made by dissolving 1 pound of copper sulphate in 1 gallon of water and adding 1 pound of sulphuric acid. (2) The other solution is made by dissolving 6½ ounces of potassium carbonate, 2 pounds of potassium cyanide, and 1 pound of copper carbonate in 3 gallons of water. The passage of any of these substances into solution may be hastened by heating the water.

The solution commonly used for nickel plating is made by dissolving ¾ pound of the double sulphate of nickel and ammonia in 1 gallon of boiling water.

The silver plating solution contains 8 ounces of potassium cyanide, 5½ ounces of silver nitrate, and 1 gallon of water. The solution is prepared as follows: The silver nitrate and potassium cyanide are dissolved separately in water and prussic acid is added slowly with constant stirring to the silver-nitrate solution. Silver cyanide, which is a white substance somewhat like milk curds, is thus formed. The addition of prussic acid must be continued only so long as silver cyanide is formed. This can be told by adding a little prussic acid to some of the clear liquid; if the liquid remains clear, enough prussic acid has been added; if it becomes milky, more should be added. Care should be taken not to add more prussic acid than is necessary. Then the silver cyanide solution is filtered through a fine cloth, which retains the silver cyanide, and water is poured through the cloth several times to wash the silver cyanide, which should then be removed from the cloth and put in the potassium-cyanide solution and stirred. If the silver cyanide does not dissolve, a little more potassium cyanide may be added. When the impurities have settled, this solution is ready for use. Potassium cyanide is a deadly poison and should be handled with the greatest care.

81. Anodes.—The anode is a piece of metal that is attached to the positive side of the electric circuit and suspended in the plating solution, so that the current passes into the solution from the anode and keeps up the metallic strength of the solution. It is usually made of the metal that is being deposited. For example, nickel is used when nickel plate is being deposited. It is, however, not always desirable to use an anode made of the pure metal. When plating with copper, the anode may be a piece of clean copper. For the nickel anode, the following alloy will serve the purpose: nickel, 92 per cent.; tin and iron, each 4 per cent. Old files may be used for the iron and the alloy should be melted in a graphite crucible.

ECONOMICS OF BRASS FOUNDING

BRASS-FOUNDRY ARRANGEMENT

82. Handling of Materials.—In order that the handling of materials in a brass foundry, such as molding and core sand, flasks, metal, fuel, castings, patterns, etc., may be reduced to a minimum, the proper layout of the foundry buildings and especially that of the molding floor is of the utmost importance. The cost of handling materials may be considerably reduced by the installation of special equipment, such as sand and casting conveyers, sand-reconditioning machines, molding machines, etc. This is especially true when the foundry is engaged in the production of large quantities of a few standard castings. As a general rule, however, the average brass foundry does not produce a standard product, but turns out castings of a varied nature and made of different alloys. The castings may vary in weight from a fraction of a pound to several thousand pounds, and it is not uncommon for a brass foundry to handle as many as ten different alloys. These conditions complicate the problem of providing an economical layout, as special machinery that would efficiently serve any one product can rarely be used in a jobbing brass foundry. The layout of a brass foundry is further governed by the space available and the volume of work handled.

83. Typical Brass-Foundry Layout.—A typical layout for a jobbing brass foundry is shown in Fig. 3. Patterns are stored at one end *a* of the foundry, and at *b* is located the foreman's office. A room for repairing patterns is provided at *c*. The furnaces *d* are of the open-flame tilting type and are placed in a straight line. Metal in the form of ingots or scrap is stored in a charging room above the furnaces. The ingot metal is brought in directly from railroad cars on the spur track *e*, and may be elevated to the charging floor by cranes or by an elevator. Scrap metal salvaged from the cleaning room may be taken to the charging floor on an outside runway *f* or by an elevator. To one side of the furnaces is placed the apparatus *g* for warming the ladles.

84. A conveyer *h*, Fig. 3, runs the length of molding floor in a depression in the floor, and serves to take the castings made by the molding machines *i* and *j* to the cleaning room *k*. The machines are grouped on either side of the conveyer and are provided with overhead hoppers for furnishing molding sand. Each of the machines *i* has its own shake-out grate *l* through which the sand from the mold drops onto an underground conveyer system that takes it to a reconditioning machine. The shake-out grates for the molding machines *j*

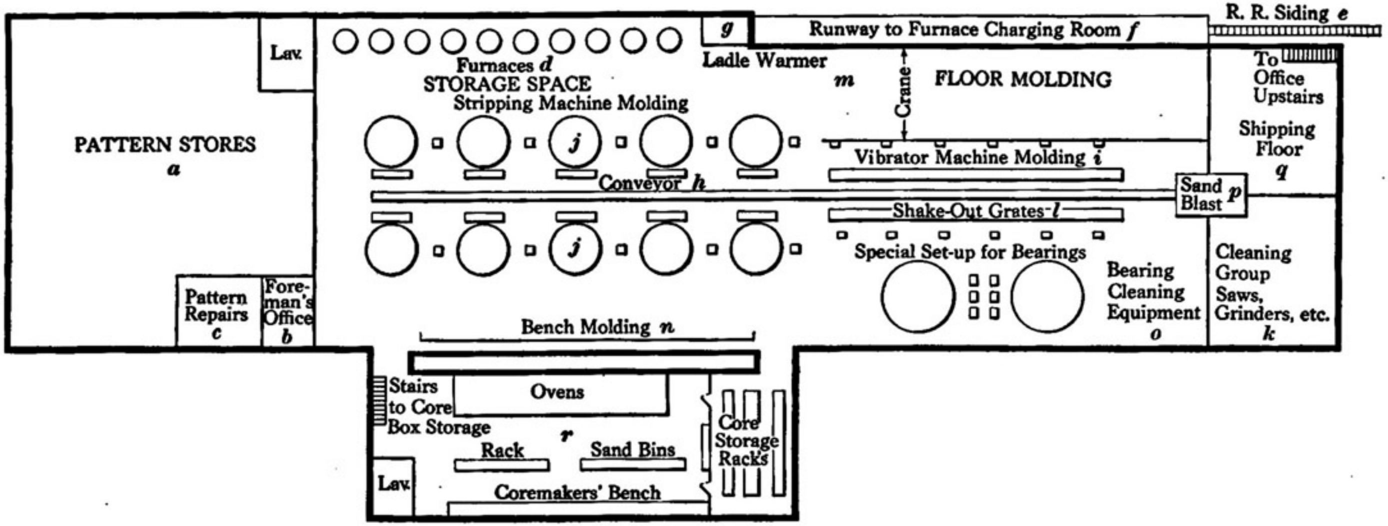

PATTERN STORES
a
Lav.
Pattern Repairs
c
Fore-man's Office
b
Furnaces d
STORAGE SPACE
Stripping Machine Molding
j
j
Conveyor h
Bench Molding n
g
Ladle Warmer
m
Crane
Runway to Furnace Charging Room f
FLOOR MOLDING
Vibrator Machine Molding i
Shake-Out Grates l
Special Set-up for Bearings
Bearing Cleaning Equipment
o
Sand Blast p
R. R. Siding e
To Office Upstairs
Shipping Floor
q
Cleaning Group Saws, Grinders, etc.
k
Stairs to Core Box Storage
Ovens
r
Rack
Sand Bins
Core Storage Racks
Lav.
Coremakers' Bench

FIG. 3

deposit the shake-out sand onto the same underground conveyer. At *m* is a space equipped for floor molding. It is located near the furnaces to minimize the transportation of the ladles of molten metal. Crane service is provided for all transportation of metal, usually by a monorail system. A space for bench molding is provided at *n*. This foundry makes a specialty of castings for bearings, and special molding machines with auxiliary cleaning equipment are placed for this purpose at *o*.

85. The castings that have been shaken out are taken by the conveyer *h*, Fig. 3, to a sandblast room *p* to be cleaned, and then to the cleaning room *k* in which band saws and grinders remove all gates, sprues, risers, and fins. Finally, the castings are taken to the shipping room *q*. The main office is located over the shipping floor, which enables the planning and cost departments to keep in touch with outgoing castings. The core room *r* is located in a small wing of the building, close to the molding floor, and has a storage for core boxes directly over the core room.

REMELTING AND RECLAIMING PRACTICE

86. Use of Old Metals.—When a brass foundry operates in connection with a machine shop, considerable old metal is returned in the form of borings and scrap brass. Other scrap brass may be obtained in the form of waste from sheet punchings, scrapped valves and pipe fittings, and miscellaneous brass castings. Copper wires in all sizes and lengths are returned to foundries working in conjunction with plants making electrical equipment. Of the white metals, babbitt and solder dross, bearing linings, etc. are often available. All of these old metals except the dross may be remelted and used. If the composition of the scrap is uniform and is the same as one of the alloys used by the foundry, it may be melted in the foundry furnaces and poured directly into molds. If not of uniform composition, the scrap is melted with sufficient additions of virgin metal to bring it to the desired composition and cast into ingots for subsequent use in the foundry.

87. Borings are usually composed of miscellaneous alloys mixed together, and nearly always contain iron. They must be passed over a magnetic separator before being melted to separate out the iron. The borings are slowly fed onto an endless belt by a hopper. As the borings come to the pulley over which the belt runs, all brass borings fall off. The belt at this point runs in a strong magnetic field, and all iron is retained on the belt until it passes out of this field. If the borings are oily, they must be dried before being passed over the magnetic separator. Otherwise, chips of brass and of iron will stick together, and separation will not be complete. After all iron has been removed, the borings should be thoroughly mixed. This is done by moving them about with a bucket conveyer, the pile being turned over three times to insure complete mixing. A sample is then melted down, usually in a crucible, and cast into an ingot, which is chemically analyzed.

Short ends, scrapped castings, waste from punchings, wire, etc., may be sorted by hand. The chemical composition of each grade of scrap is usually known or it may be determined by analysis. All miscellaneous castings and odds and ends may be allowed to accumulate in a pile. Then samples are picked out more or less at random, melted, and run into an ingot, and analyzed. This process, although rather haphazard, will give the composition of the whole pile with a surprising degree of exactness.

88. Reclaimed-Metal Mixtures.—Mixtures are made up from these old metals based on known analyses, and are run into ingot form. The melting is usually done in a large open-flame tilting furnace, the melted metal being poured into a large ladle and transferred to the ingot molds. These are made of cast iron and are placed in long rows. Enough molds are provided to permit the pouring off of an entire heat at one time. When the metal cools, it shrinks and permits the easy removal of the metal from the mold. Ingots are made light enough so that they may be handled by one man. The common weight of an ingot is between 90 and 100 pounds, but in some cases may exceed this amount.

89. The charges that are to be melted are usually made up by the foundry metallurgist. Suppose, for example, that it is desired to make 5,000 pounds of an alloy containing 85 per cent. of copper, 5 per cent. of zinc, 5 per cent. of tin, and 5 per cent. of lead, and that there are available for remelting 10,000 pounds each of the following alloys:

Alloys	Copper Per Cent.	Tin Per Cent.	Zinc Per Cent.	Lead Per Cent.
No. 1	80	10	5	5
No. 2	90		5	5

The desired alloy evidently has the following composition by weight: copper 4,250 pounds, tin 250 pounds, zinc 250 pounds, and lead 250 pounds. If, then, 2,500 pounds each of alloys No. 1 and No. 2 are melted together, the result will be:

Alloys	Weight Pounds	Copper Pounds	Tin Pounds	Zinc Pounds	Lead Pounds
No. 1	2,500	2,000	250	125	125
No. 2	2,500	2,250		125	125
Total ...	5,000	4,250	250	250	250

The total weight and composition of the mixture answers the requirements for the desired alloy.

If no alloys that will give the exact alloy wanted are available, additions of pure metals must be made to the mixture. Assume, for instance, that it is required to make up 3,000 pounds of an alloy containing 84 per cent. of tin, 11 per cent. of antimony, and 5 per cent. of copper, and that the only alloy available that contains these metals has the following composition: tin 83 per cent., antimony 9 per cent., and copper 8 per cent. According to the analysis of the required alloy it has the following composition by weight: tin 2,520 pounds, antimony 330 pounds, and copper 150 pounds. It will be noted that, in determining the weight of the available alloy to be used in approximating the composition of the required alloy, the weight of the copper, being the smallest in percentage, is the limiting factor. A few trial calculations will show that 1,800 pounds of the available alloy have a composition by weight as follows: tin 1,494 pounds, antimony 162 pounds, and copper 144 pounds. The weight of the copper approaches very closely the weight of the copper in the desired alloy, namely, 150 pounds, and it is therefore safe to limit the amount of available alloy that can be used to 1,800 pounds, adding to it the amounts of pure metal as follows:

	WEIGHT POUNDS	TIN POUNDS	ANTIMONY POUNDS	COPPER POUNDS
Available alloy	1,800	1,494	162	144
Pure metal added	1,200	1,026	168	6
Total	3,000	2,520	330	150

90. Considerable skill and experience on the part of the metallurgist is required to reduce the amount of pure metals to be added in making an alloy of a definite composition to a minimum. In some cases, the addition of large amounts of pure metal can be avoided, with only slight sacrifice in the final make-up of the mixture, by melting together five or six different alloys. Usually, amounts of metal slightly in excess of those theoretically required are added to care for losses during melting.

Mixtures that are to be poured directly into molds should not be composed of more than two-thirds new metal, as otherwise the resulting metal will not be of uniform composition. It takes an appreciable time for the metals to mix thoroughly, and the time in which the metal is commonly melted is not enough. If a large amount of new metal must be used, the mixture should first be run into ingot form and later remelted. If the amount of new metal added is not too large, the effect is often beneficial to the mixture. When scrap is melted over and over again, the metal often becomes brittle and drossy, and acquires a tendency to absorb impurities, so that new metal should be added from time to time to keep it in condition.

91. Recovery of Waste Metals.—The metals that are used in the brass foundry are of such high intrinsic value that it pays to recover them whenever possible. Foundry waste that may contain metal in sufficient quantity to warrant recovery are slag, skimmings and dross, metal spilled during pouring which has become mixed with molding sand, grindings and dust from the cleaning room, floor sweepings, ashes from coal or coke furnaces into which metal has been spilled, mud from tumbling barrels and old crucibles, etc. The manner in which this metal is recovered depends on the size and location of the foundry and the policy of the management. Small plants usually sell their waste to smelters, while large plants often do their own refining. Other plants retain the larger pieces of metal and sell the lower grade waste to smelters. When the size of the foundry warrants the investment, concentrating and refining equipment will prove very profitable.

92. Spilled metal, when not mixed with other alloys or with too much dirt, may be charged back into the melting furnace. Some foundries charge skimmings from one heat back into the next. Foundry waste is often run through a tumbling barrel containing steel balls through which a stream of water flows. The steel balls break up the waste, and the water carrying away the light non-metallic substances, leaves the larger pieces of metal in the barrel. These pieces are rich in metal and usually warrant further concentration. Besides wet-ball mills, rolls, jaw crushers, and stamp mills are used to break up waste material. The crushed material is then put through some form of concentrating equipment.

93. Water-Table Separator.—There are a number of different devices that separate the brass from the waste material, all of which operate on the principle that flowing water will carry off the light material and leave the heavier metal behind. A water-table separator is shown in Fig. 4. Water carrying the crushed metal and waste from the mills is delivered into the trough *a* by the pipe *b*. The material flows from the trough onto the table *c*. A system of baffles *d*, consisting of strips about $\frac{1}{4}$ inch wide and $\frac{1}{16}$ inch high, causes the material to spread out in a thin layer all over the table. As the water containing the crushed material flows over these strips, the metal is caught and held by them while the lighter waste is carried by the water

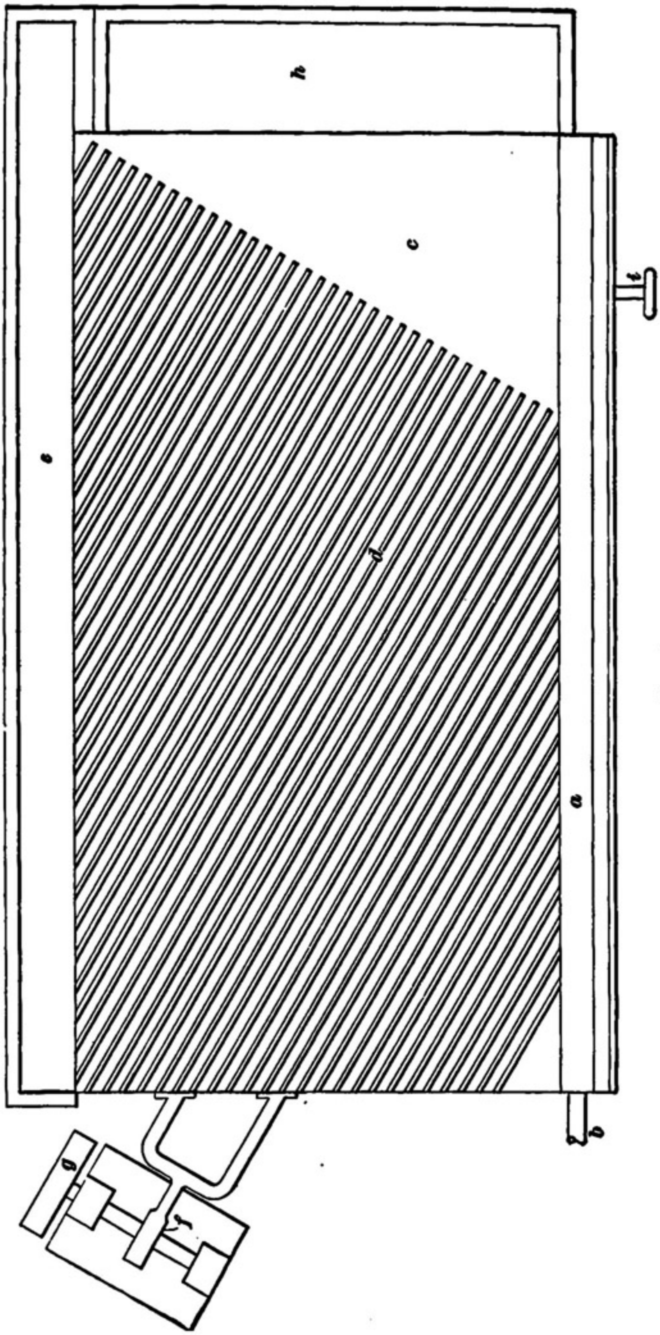


FIG. 4

to the chute *e*. During concentration, the table is continually rocked back and forth by the eccentric *f*, which is driven by the pulley *g*. The length of the table travel is about ½ inch. This oscillation causes the metal to work down to the lower end of the table, where it falls into the box *h*, from which it is collected. The angle at which the surface of the table is tilted may be varied by the hand wheel *i* to regulate the flow of water over the table.

94. The metal reclaimed in this manner is known as concentrated waste, and, since it is not pure, it must be refined before it is fit for castings. A reverberatory furnace, fired by coal or oil, is commonly used for this purpose. The dross and slag are skimmed off and the cleaned metal is tapped out. The furnace operates continuously, being recharged before all the previous charge has been drawn out. The skimmings from this process still contain some metal, and they may be remelted in a cupola, which separates out all the metal that may be recovered profitably. Reverberatory ingots contain but little zinc, most of it being burned out during melting. Only the larger pieces of metal that are recovered by the wet-ball mill contain all the original alloy.

95. Melting Ratio and Yield.—To make a casting, considerably more metal must be melted than is required by the casting itself. In the first place, there is a certain percentage of metal lost during melting. More metal is lost in the form of dross, and some metal is almost certain to be spilled during pouring. Considerable metal is required to fill sprues, gates, and risers, often more than that required for the casting itself. Again, a certain amount of surplus metal is cast into an ingot and set aside as a reserve supply.

The ratio of the pounds of metal melted to the pounds of metal in the finished casting is known as the *metal ratio*, or *yield*. The furnace tender must know the approximate metal ratio for any kind of casting in order that he may melt enough metal to pour off the molds and have little if any left over. The metal ratio varies with the composition of the alloy and with the ratio of the area of the casting to its finished weight.

TABLE XV

METAL RATIOS

Alloy Number	Copper Per Cent.	Zinc Per Cent.	Tin Per Cent.	Lead Per Cent.	Aluminum Per Cent.	Ferro Manganese Per Cent.	Iron Per Cent.	Manganese Per Cent.	Class	Metal Ratio
1	100									3.25
2	80	10			.5	9.5				2.00
3	70	10			1.	19.				3.50
4	76	18	3	3					Medium	
									ınd Large	2.60
									Small	8.00
5	87	5	7	1						2.00
6	55	42	1¼		⅛		1½	⅛	Large	
									Rings	2.00
									Miscl.	3.00
7	90		10							2.85
8	79		10	11						1.80
9	92	2	6							3.20
10	86	8	3	3						4.40
11		33⅓			66⅔					2.50
12	8				92					2.75

The amount of metal to be melted may be calculated from the composition of the alloy and the weight of the finished casting, without considering the area of the casting. The average ratio for any alloy may be found by dividing the pounds melted during a given period by the number of pounds of castings made from that alloy and shipped during that same period. The longer the period, the more nearly correct will be the average metal ratio. By multiplying the average metal ratio by the average weight of the finished casting, the weight of metal to be melted can be computed. A few non-ferrous alloys and their metal ratios are given in Table XV.

96. Heat Treatment of Non-Ferrous Alloys.—The heat treatment of non-ferrous alloys is not yet used to a great extent. However, considerable investigation on this subject is in progress. The treatments consist of heating to various temperatures and then cooling at various rates and to different extents. The purpose of the treatments is to release the casting strains, to prevent warping and cracking, to increase the strength and ductility, to soften or harden the metal, and to vary the properties or crystallization to suit the needs of any special service. The aluminum alloys are probably receiving the most attention at present. The heat treatment of duralumin, a very important alloy of aluminum, is given in Art. **20.** In general, the heat treatment consists of heating to a predetermined temperature and quenching, heating again to the proper temperature, and drawing. The heat treatment of gears and bearings is the most common application.

97. Brass-Foundry Hazards. — Aside from the usual danger from burns and explosions common to all foundries, there are several hazards to health in a brass foundry not found in any other. Some of the metals handled in a brass foundry, such as lead, are poisonous in their natural form, whereas others give off poisonous fumes when being melted, as in the case of copper and zinc. The inhalation of brass dust from grinders and cleaning apparatus may cause serious illness due to the poisonous effect of brass dust on the lungs. The fumes of zinc and zinc oxides are particularly injurious and often are the cause of the peculiar illness common to the brass molder, known as "the shakes." The careless handling of lead may lead to lead poisoning, and carbon monoxide gases from furnaces, core ovens, mold driers, etc., may cause suffocation. To prevent these dangerous conditions it is necessary to avoid the production of metallic fumes, to have proper and abundant ventilation, and to observe the laws of personal hygiene.

BRASS AND ALLOY FOUNDING

Serial 2331B (PART 2) **Edition 1**

BRASS MELTING FURNACES AND PRACTICE

FURNACES

CRUCIBLE FURNACES

1. Single-Pit Crucible Furnace.—There are four kinds of furnaces used for melting non-ferrous metals for castings. These are the crucible, the cupola, the open-flame, and the electric furnace.

2. The crucible furnace is commonly built in a pit so that the top of the furnace is at or near the level of the foundry floor. In Fig. 1 is shown the section of such a furnace that burns coal or coke fuel. It is built below the floor level *aa* and consists of a sheet-iron shell *b* lined with firebricks *c*, resting on a bedplate *d*, and fitted with a cast-iron cover *e*. The covers are usually provided with a refractory lining. Two bearing bars *f* support the loose grate bars *g*. The ash-pit *h* is usually from 12 to 18 inches deep. The products of combustion pass through a flue *i* near the floor line *aa*.

The flue should have a diameter equal to about one-third that of the furnace and be connected to a chimney or flue that has an area at least as large as the furnace, and which is high enough to give a good draft. The height of the chimney will depend to a great extent on the surroundings. The flue *i* should be lined with firebricks or fireclay to protect the shell *k*; some founders use a cast-iron pipe, however, for a flue and renew it whenever it is burned away. The top of the furnace is generally from 6 to 12 inches above the level of the floor line *aa*. The inside diameter of the lining is generally from 6 to 8 inches larger than the greatest diameter of the largest crucible that will be used, as experience has demonstrated that a coke bed about 3 inches thick around the crucible gives the greatest melting efficiency.

3. The furnace is usually of such a height that the top of the crucible will be within 3 inches of the bottom of the flue *i* when there is about 9 inches of fuel under the crucible.

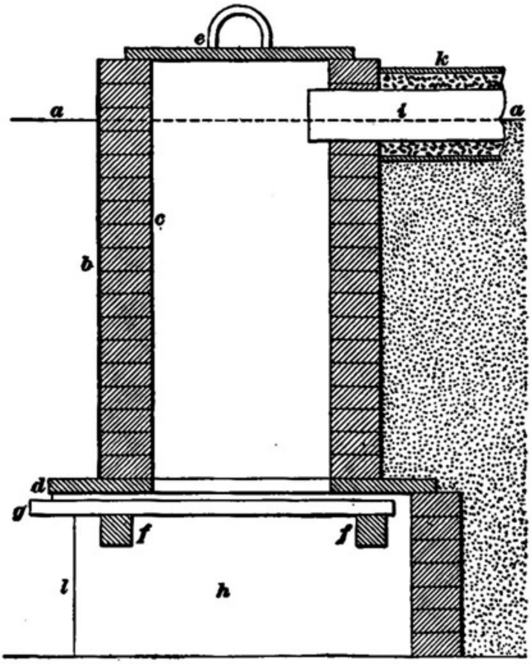
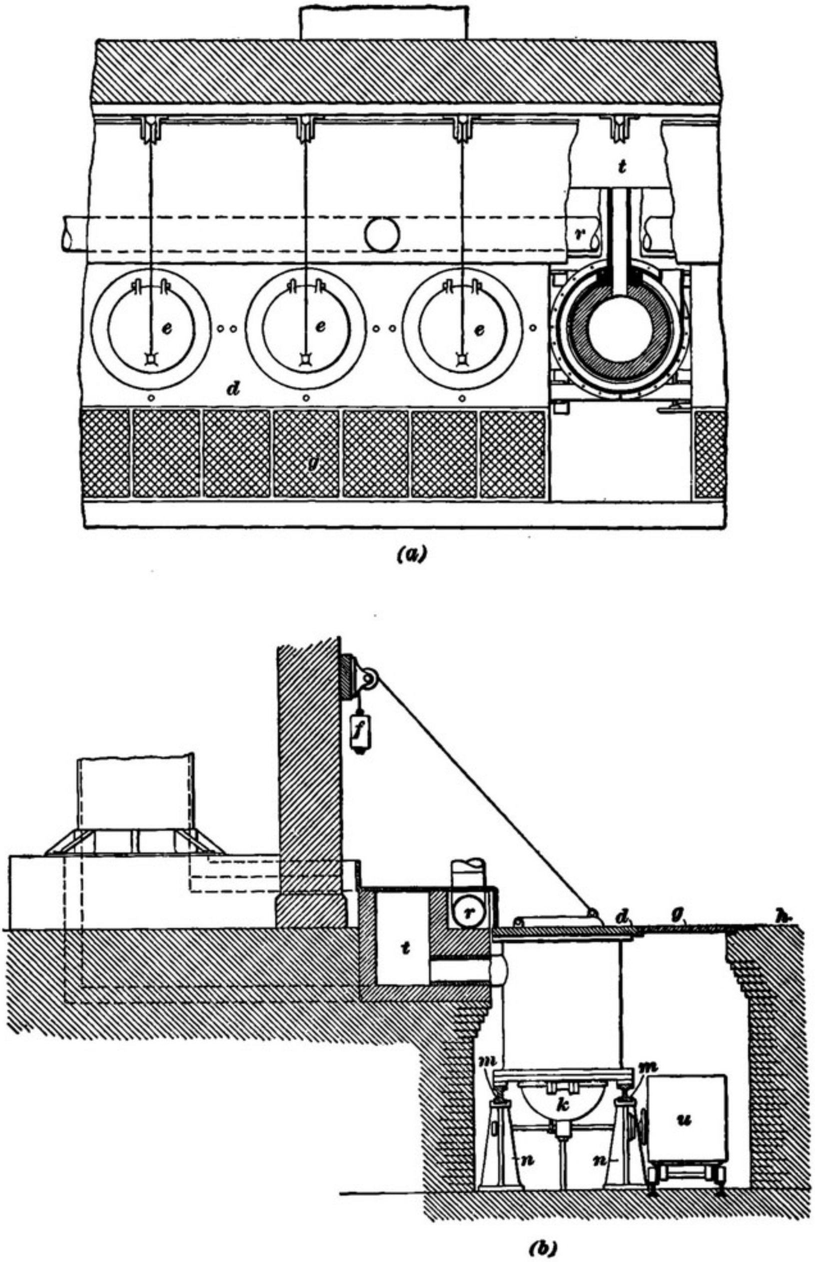


FIG. 1

The grate bars *g* have considerable influence on the character of the draft. They may be plain, straight, cast-iron, or wrought-iron bars; or the grate may be one circular casting. If made of separately cast bars, it is well to have lugs cast near their ends, to keep them at a uniform distance from one another, thus allowing a uniform draft to pass through the fire and giving better combustion in the furnace.

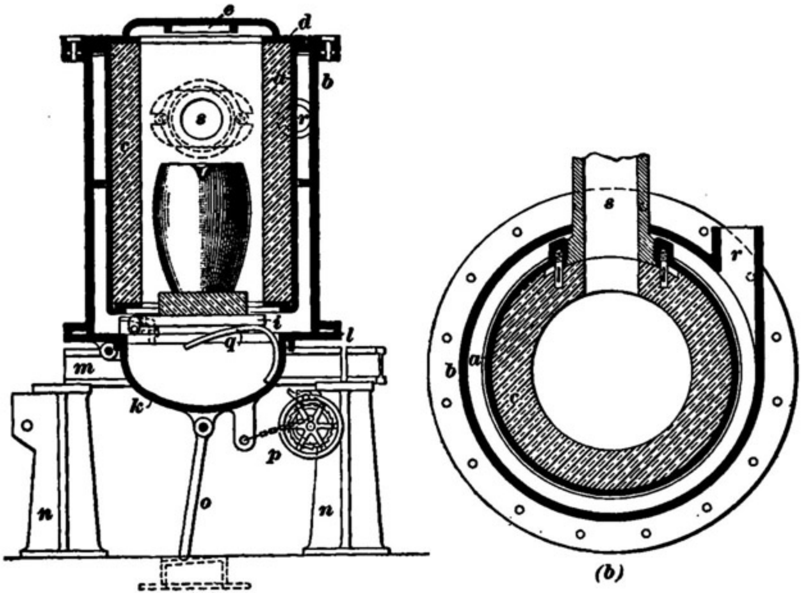


(a)

(b)

Fig. 2

4. Crucible Furnaces in a Battery.—When more than one crucible furnace is required and where they can be connected all the flues may lead to one main flue that connects with a chimney placed midway between the furnaces; for, if the chimney is at one end of the row, the furnace that is farthest away may suffer for lack of draft. The main flue should have an area equal to the combined area of the flues that form the branches. When natural draft is depended on, every care should be taken to have it as good as is possible under the existing conditions, for if the draft is light the speed of melting will be low and the quality of the metal poor.



(a) (b)

FIG. 3

5. Another furnace that is used in the brass foundry is shown in Figs. 2 (*a*) and (*b*), and 3 (*a*) and (*b*). Fig. 2 (*a*) is a plan view of a battery of four furnaces and a sectional view of one; (*b*) is an end elevation. The furnace consists of two cast-iron cylinders *a*, *b*, Fig. 3 (*a*) and (*b*), one within the other with an air space between. The inner one is lined with firebricks *c* and has a square top cover *d*, Fig. 2 (*a*), with a circular door *e*, which is counterbalanced by means of a chain and weight *f*, Fig. 2 (*b*). The covers *d* of the furnaces with the gratings *g* over the ash-pit make a continuous platform on the floor level *h*, as shown in view (*b*). A hinged grate *i*, Fig. 3 (*a*), forms the bottom of the inner cylinder and a spherical door *k* hinged to the circular bottom casting *l* closes the bottom of the outer one. The whole furnace is supported by **I**-beams *m* on posts *n* resting on foundations below the level of the ash-pit floor, as shown in Fig. 2 (*b*). The lower door *k* is held securely in a closed position by a hinged prop *o*, Fig. 3 (*a*), and is opened and closed by means of a chain wound on the shaft of a hand wheel *p*, and a ratchet and pawl. The bottom *k* is made bowl-shaped so as to serve as an ash receiver and also large enough to hold the metal if a crucible should break. A heavy curved piece of iron *q* fastened to the inside of the bowl lifts and holds the grate *i* in position. The blast from the blower enters at *r* and the burned gases pass through the upper openings *s* to the stack, as shown in Fig. 3 (*b*). The blast pipes *r* are laid along the smoke flue *t*, Fig. 2 (*a*) and (*b*), and the air flows through the heated space between the cylinders *a*, *b*, as shown in Fig. 3 (*a*) and (*b*). This plan utilizes considerable waste heat and greatly reduces the time necessary to melt the charge. An ash car *u*, Fig. 2 (*b*), runs on tracks in the pit and is lifted from the pit by means of a pneumatic hoist operating on an overhead trolley; the hoist also serves to handle the crucibles. In many cases chain hoists are used for handling the crucibles.

6. Combined Cupola and Crucible Furnace.—In Fig. 4 is shown the sectional view of a cupola furnace arranged with a sand bottom, so that the metal may be melted in direct contact with the fuel; or, by replacing the sand bottom with a grate, the metal may be melted in crucibles. When using this furnace without a grate for melting copper, the blast must be much milder than when melting iron, and from one-eighth to one-fourth more fuel must be used. In preparing the furnace, the daubing should be put on thinly and the surface should be blacked over, as in blacking a dry-sand core or dry-sand mold, for the cleaner the metal is kept in melting it, the better will be the results in casting.

7. When crucibles are used in the furnace shown in Fig. 4 they should be charged in the same manner as in the regular crucible furnace. They should be set in the cupola on a bed of fuel ranging from 8 to 10 inches in depth; fuel should be placed around their sides and the blast applied, instead of using the natural draft. A very high temperature may be obtained in the furnace shown in Fig. 4, but the amount of coke burned per pound of metal is very large. The high temperature obtainable in this furnace permits its use for the melting of nickel and its alloys, which require the highest tempera-

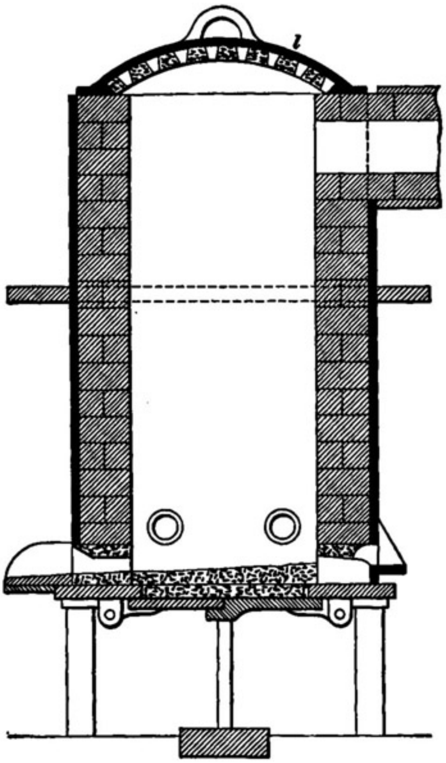


FIG. 4

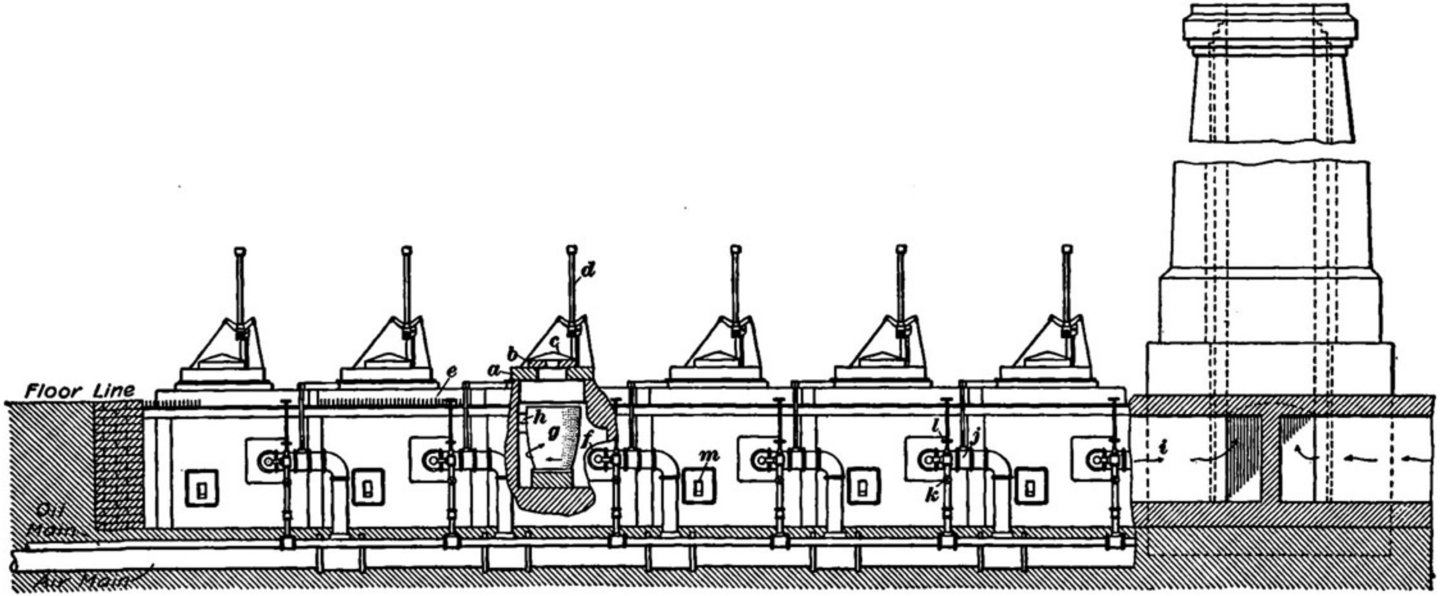


FIG. 5

ture of any of the metals or alloys commonly used in the brass foundry.

8. The furnaces shown in Figs. 5 and 6 are built in a pit like the furnaces shown in Figs. 1 to 3. The fuel is, however, oil or gas instead of coal or coke. Fig. 5 is a front view of these furnaces, one being sectioned through the middle. Fig. 6 is a side view of one of these furnaces and shows the course of the hot gases through the furnace to the chimney flue.

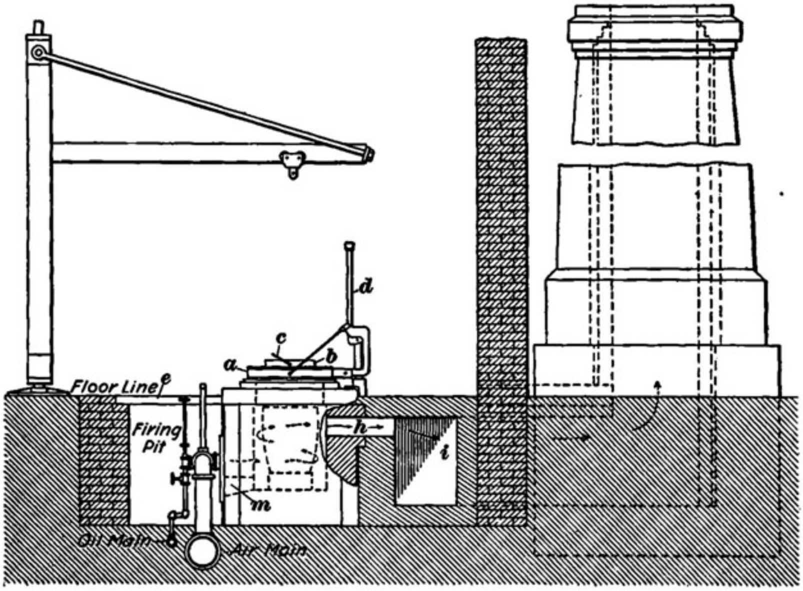


Fig. 6

The furnace consists of a rectangular steel shell lined with fireclay tile, and the top is closed with a double cover. The main cover *a* is made of fireclay bound with an iron band. There is a hole in the middle of this cover through which the metal in the crucible may be observed and through which small amounts of metal may be added to the charge. This hole is closed by a second cover *b* which is like the first one, except that it is smaller and the hole through it is tapered and is closed by a clay plug. The small cover *b* is provided with a bail *c* by which it may be lifted off when necessary. Both covers may be lifted and swung to one side by means of the lever *d*.

9. In front of the furnaces is a firing pit covered by a grating *e*, Fig. 6, the top of which is on a level with the floor. The pipes through which oil and air are brought to the furnaces are laid in the floor of the firing pit. The smaller of the two pipes is the oil pipe and the larger is the air pipe. When gas fuel is used instead of oil, the gas comes to the furnace through the smaller pipe. Branch pipes lead from the main pipes to the burners *f*, Fig. 5, which are placed at one side of the furnace so that the flame and hot gases do not strike directly on the crucible *g*, but circulate around it and finally pass through the opening *h*, Fig. 6, to the flue *i*, which leads to the chimney.

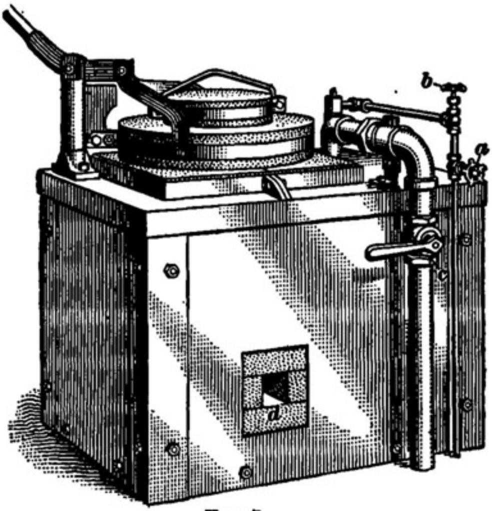


FIG. 7

10. The supply of oil and air to the burners is regulated by valves placed near the burner. The valve *j*, Fig. 5, in the air pipe has a handle above the floor so that the supply of air can be readily controlled. The oil pipe has two valves, *k* and *l*. The valve *k* is the shut-off valve; it should always be either wide open or shut tight. The quantity of oil supplied to the burner is regulated by the valve *l*, which has a long stem reaching above the level of the floor and having two hand wheels, one near the valve and the other where it may be reached from the floor level.

If a crucible should break, the metal would run down into the bottom of the furnace, from which it may be tapped through the opening shown at *m*.

11. The furnace shown in Figs. 7 and 8 resembles those illustrated in Figs. 5 and 6. This furnace may be set in a pit, but it is especially well adapted to locations in which the pit construction is not suitable. Fig. 7 is an outside view of the furnace, and Fig. 8 is a sectional view of it. This furnace differs from the pit furnace just described, in the position of the burner, which is placed so that it directs the flame against the bottom instead of the side of the furnace. The flame and hot gases then pass up around the crucible and through an opening, not shown, to the chimney. The oil is turned on or off by the valve *a*, the amount of oil is regulated by the valve *b*, and the air supply is controlled by the valve *c*, which is shut off when the handle is in the position shown. Should a crucible break, the metal may be tapped out through the opening shown at *d*.

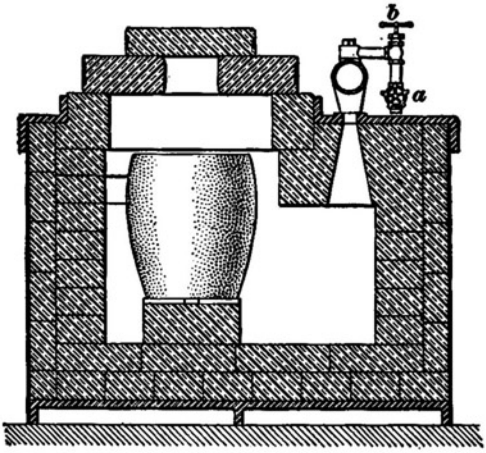


Fig. 8

Temperatures high enough to melt the most refractory metals with which the brass founder has to deal, are said to be obtainable in this furnace. The lining, which is made of standard firebricks, must be capable of withstanding these temperatures. The courses of bricks next to the shell are not subjected to a temperature that damages them, and therefore the inner course needs most frequent repair and renewal.

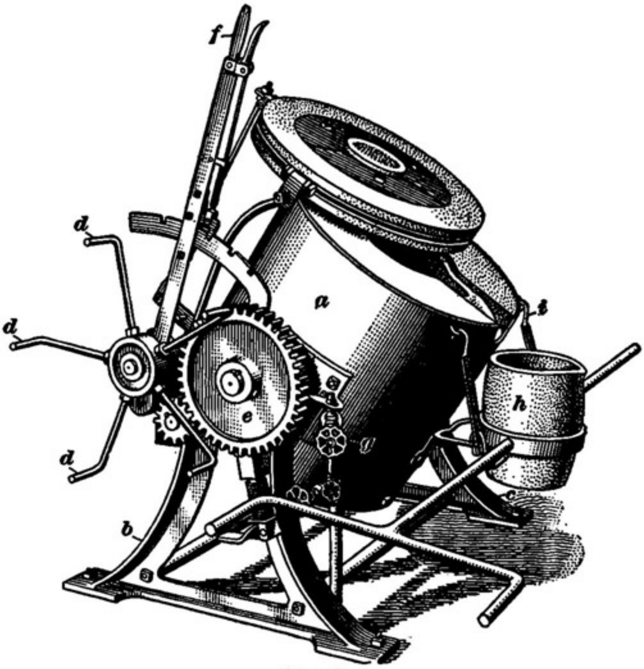


FIG. 9

12. Tilting Crucible Furnace.—The crucible is not removed from the tilting crucible furnace when the metal is to be poured; instead, the furnace is tilted and the metal is poured into another crucible, in which it is carried to the mold. In Fig. 9 is shown a tilting crucible furnace. It consists of a steel shell *a* supported in bearings on the standards *b* and *c*. The furnace is tilted by means of the handles *d* and the gearing *e*. The cover is lifted and swung on or off the furnace by the lever *f*.

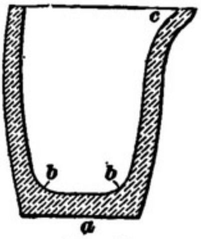


FIG. 10

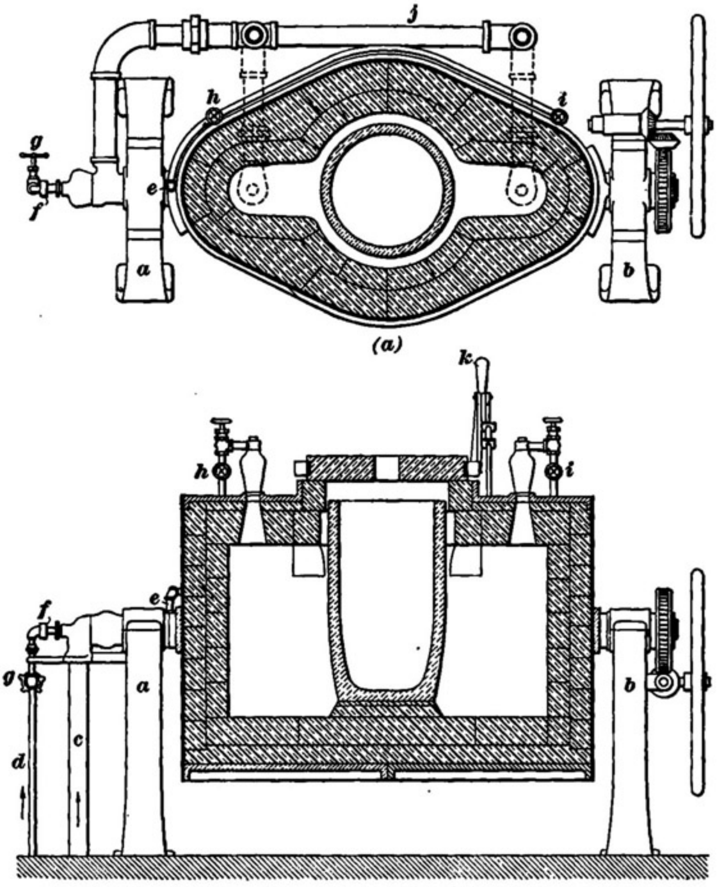
The shell *a* is lined with bricks or tile made of fireclay, an opening being left in the center for the crucible. In Fig. 10 is shown one of the crucibles that has been cut in two. It has a wide, flat bottom *a,* rounded corners at *b,* and a long spout *c.* It is made of graphite and rests on a fireclay tile in the bottom of the furnace *a* in Fig. 9.

This furnace burns either oil or gas, the burner being just back of the valve *g* in Fig. 9. A hole is so placed in the shell *a* and the furnace lining, that when the furnace is in the upright or melting position, the hole comes opposite the burner. The flame strikes one side of the tile on which the crucible stands and then passes up around the crucible through passages, not shown, in the furnace lining and out through the hole in the middle of the cover.

The metal is poured, when melted, into the crucible shown at *h.* This crucible is hung on a couple of links *i* so that it will swing out as the furnace is tilted and will remain under the spout at all times.

13. Another style of tilting furnace is shown in Fig. **11.** A sectional top view of the furnace is shown in (*a*), and a sectional side view is shown in (*b*). The steel shell of the furnace is supported on trunnions in bearings on the pedestals *a* and *b,* and is lined with two thicknesses of fireclay tile. The furnace is provided with two burners and it therefore has two combustion chambers, one placed at each side of the crucible. The flame is directed against the bottom of the furnace and the products of combustion pass up and around the crucible and out through the hole in the cover. A funnel-shaped hood should be placed over the furnace so that the products of combustion will be taken up the chimney instead of being dissipated through the foundry. Some of these gases are extremely poisonous, so that thorough ventilation of the foundry is important when a furnace is used that is not directly connected with the chimney.

14. The air pipe *c,* Fig. 11 (*b*), is connected to the left-hand trunnion by a joint that permits the tilting of the furnace. The oil pipe *d* is led in through the center of the air pipe and the trunnion to *e,* when the oil pipe that is fastened to the furnace is connected. The oil pipe is provided with a swivel joint at *f,* so the furnace may be turned independently of the pipes *c* and *d,* which remain stationary. The oil pipe is also equipped with a shut-off valve at *g,* below the joint *f,* and there are regulating valves at *h* and *i* for the control of the oil supply to the burners. The air supply to the burners is controlled by valves in the branch pipes that lead from the main air pipe *j* to the burners, and these valves serve also as air shut-off valves. The cover is lifted from the furnace by means of the lever *k.* While the metal is being poured the cover need not be lifted very far and it will then protect



(b)

FIG. 11

the men who may be working around the furnace from the heat. When, however, the furnace is to be charged, the cover may be swung back out of the way.

15. Furnace for Aluminum.—A type of tilting furnace most commonly used for melting aluminum is shown in Fig. 12. This furnace uses oil fuel; but where gas is available as a by-product in the plant, this furnace is made with a hollow trunnion for the gas and air connections. The furnace is set in standards with its trunnion geared to a pilot wheel for tilting. The oil burner *a* is attached to a bracket cast on the standard and is not movable, so that the furnace opening *a′* swings away from the burner when the furnace is tilted, as shown. Therefore, the oil fuel should be shut off before tilting so that the flame outside the furnace will not interfere with the ladle carriers. For gas fuel the burner is attached to the shell and extends into it about 3 inches and the fuel does not have to be shut off when tilting, except for economy. A cast-iron melting pot *b* is used instead of a crucible. Though aluminum will absorb iron as an impurity, it has very little affinity for pure cast iron. In some cases a coating of lime compound or

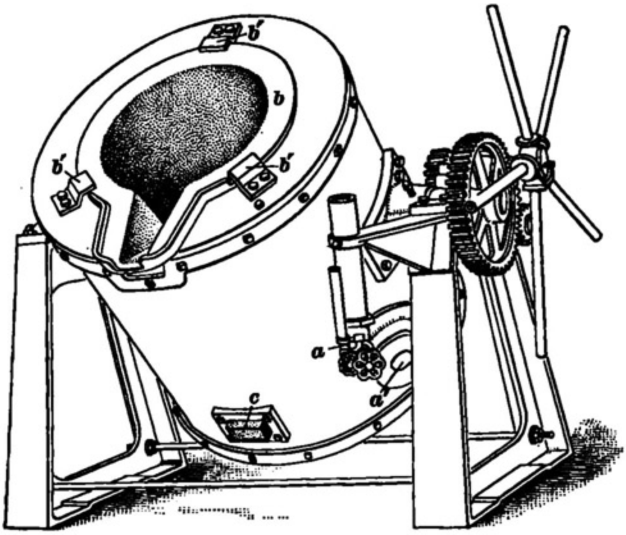


FIG. 12

of aluminum varnish is put on the pots to prevent the absorption of iron. The flame is directed around the pot and not directly against it. The shell has a thick lining. The pot *b* is suspended by its wide flange from the top of the furnace and held by three clamps *b′*. It has a spherical bottom enclosed by a rather large cylindrical flame space, which has an opening at *c* as a convenience for cleaning and inspection. The opening is usually closed with a brick. No cover is used on the pot.

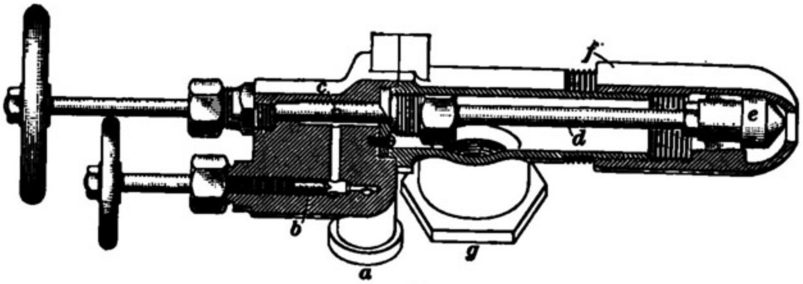


FIG. 13

16. Oil Burner for Aluminum Furnace.—The oil burner used on the aluminum furnace, Fig. 12, is shown in Fig. 13. The oil under considerable pressure enters the burner at *a* and its flow is regulated by the needle valve *b*. It passes through holes *c* into the hollow stem *d*, which is adjustable horizontally, so that its nozzzle *e* has the correct position in the opening of the cap *f* to atomize the oil. The air supply flows in at *g* and entirely surrounds the nozzle *e*. The tip end of the burner is located about 1 inch from the opening in the shell of the furnace shown in Fig. 12. This permits tilting of the furnace as previously described. It also allows air from around the burner to be drawn into the furnace by the suction of the atomized blast. This secondary air is important, as it produces a soft flame that does not overheat the iron pot and the lining, thereby prolonging the life of these parts.

OPEN-FLAME FURNACES

17. Single Chamber Open-Flame Tilting Furnace.—While the crucible method is a very common one for melting brass, it is also melted in contact with the flame in furnaces that use crude petroleum or gas for fuel. In Fig. 14 is shown one form of oil-burning furnace. It consists of a pear-shaped boiler-plate shell *a* mounted on trunnions *b*, *b′* supported by standards on substantial foundations. The bottom *c* is removable for the purpose of lining the shell *a* with firebricks, making repairs, etc. After the bottom *c* is bolted in place, the materials for its lining are introduced through the hinged charging door *d* at the top of the furnace. The furnace is tilted and held in any desired position by means of a wormwheel *e* on the trunnion *b′* and a worm and bevel gears operated by a hand wheel *f*. The air and oil enter the furnace near the top through two tuyères *g*, placed at an angle to each other and pointing downwards. The oil pipe *h* and the air pipe *i* are connected to the movable parts on the furnace by means of stuffing boxes at the end of the trunnion *b*. The furnace is heated to its working temperature before the charge is put in. To aid in preventing excessive oxidation of the charge, it is covered with some

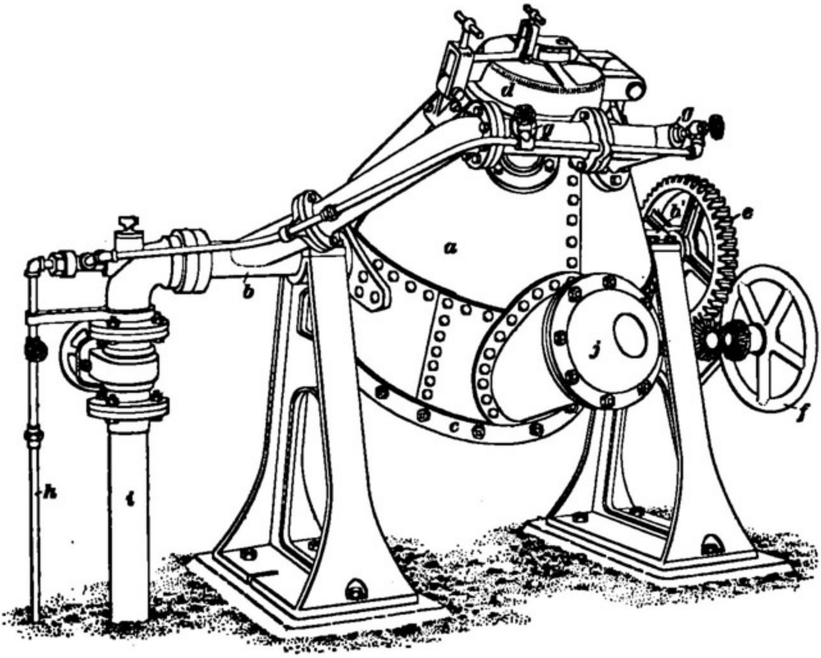


Fig. 14

material to protect it; a small amount of fine anthracite coal is sometimes used for this purpose. When the charge is melted, it is emptied into ladles through the brick-lined spout *j*, which is also the outlet for the flame and products of combustion; the operation of the furnace is judged by observing the flame that issues from the spout. The advantages of this furnace are that a larger amount of metal can be melted in one bath than where crucibles are used, and a greater amount of metal can be melted in a given time per square foot of floor space occupied by the furnace.

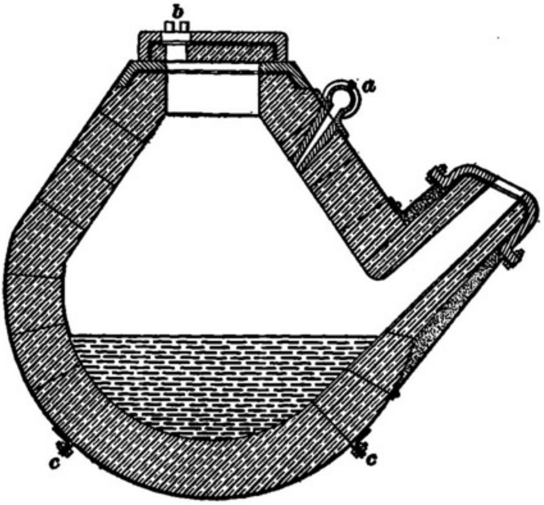


FIG. 15

18. A sectional view of a furnace of this type is shown in Fig. 15. The furnace illustrated is lined with firebricks, which are made to fit the shape of the furnace. This furnace has but one tuyère, shown at *a*, and there is a peep hole *b* in the cover. Sometimes the bottom, which is bolted on at the flanges *c*, is fitted with a plastic lining made of equal parts of ganister, or crushed quartz, silica sand, and fireclay. The lining may be patched, when necessary, by a mixture of silica sand and fireclay.

19. Double-Chamber Open-Flame Tilting Furnace.—An open-flame furnace, in order to give nearly continuous melting

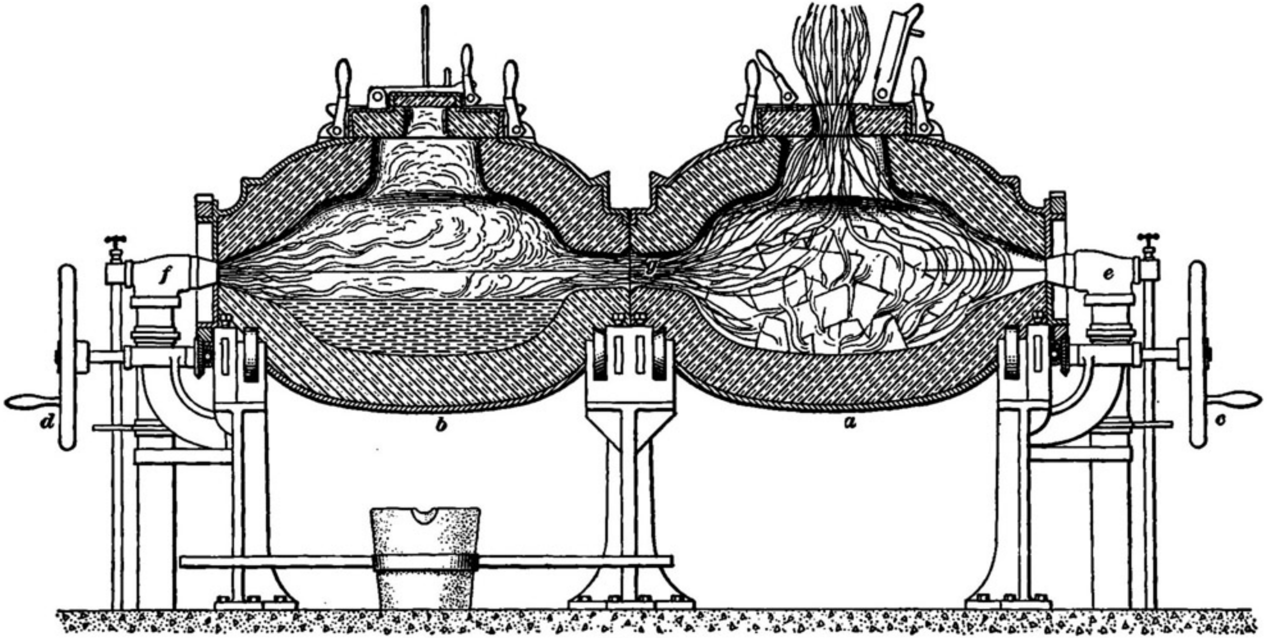


Fig. 16

with fuel economy, is divided into two chambers, as shown in Fig. 16 at *a* and *b*, each of which may be rotated independently of the other by hand wheels *c* and *d*. The furnace has two burners *e* and *f*, but only one is used at a time. The exhaust heat from the active chamber *a* passes through the port *g* into the other chamber. If a charge of metal is placed in chamber *b*, it will heat to very near the melting point while the charge in the active chamber *a* is being melted. The metal in the second chamber is thus brought up to the melting point gradually by the exhaust heat from the first one. When the direct heat is turned on, the metal melts very rapidly and with less loss from oxidation.

Each chamber of the furnace consists of a lined steel shell split lengthwise into two halves that are hinged together. In order to line the furnace, the two half shells are unbolted and opened. A form is placed in each shell and the lining material is rammed around this form. When the halves have been closed and bolted together, the lining may be dried out and "burned in" in about 2 hours. As the lining at the junction *g* of the two furnaces receives the heat of the flame continuously, its life is comparatively short. Open-flame stationary-hearth furnaces are used for the largest production.

ELECTRIC NON-FERROUS MELTING FURNACES

20. Types of Electric Furnaces.—There are three types of electric furnaces used for melting brasses, bronzes, and other non-ferrous alloys. All of these use alternating current, and they are known as the *indirect-arc furnace*, the *induction furnace*, and the *resistance furnace*. The indirect-arc furnace heats the charge of metal from the arc drawn between the ends of two large carbon or graphite rods, or electrodes, located over the charge. The arc is not in or against the charge itself, and therefore the heating is indirect. The arc gradually consumes the electrodes. The induction furnace makes use of a portion of the molten metal itself as the secondary circuit of a single coil, or turn, to carry the induced current; so that the heat is applied by the flow of a heavy current through the charge. The resistance furnace has a special *resistor* that becomes heated by the flow of a heavy current through it, and the charge of metal becomes heated by the transmission of heat from the resistor and by that reflected from the roof and other parts that may be affected by the heated source. There is no flame in the induction and resistance furnaces. All electric furnaces require the use of a superior heat-resisting and insulating lining, and within this lining there are usually two layers of thick refractories that will withstand the high temperature as well as the abrasion and fluxing action of the molten metals. The resistance type of furnace is very little used in melting operations, but its principle is adapted to the heating of core ovens and annealing furnaces.

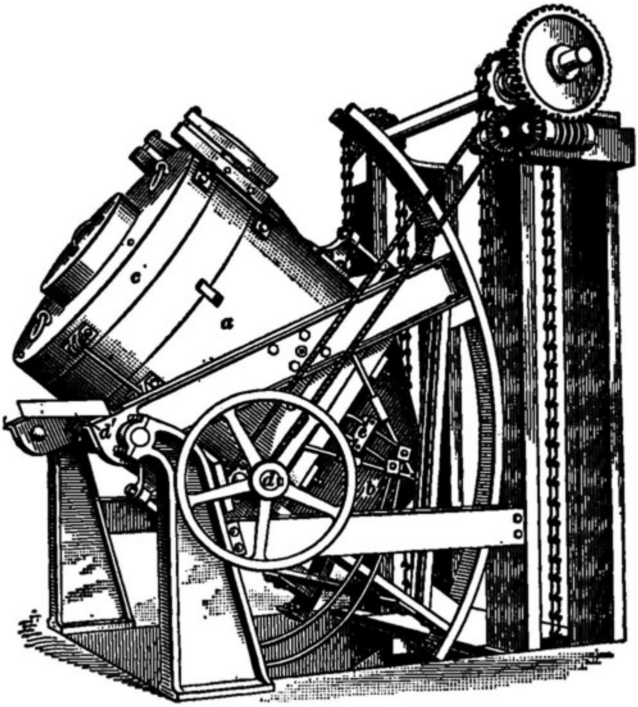
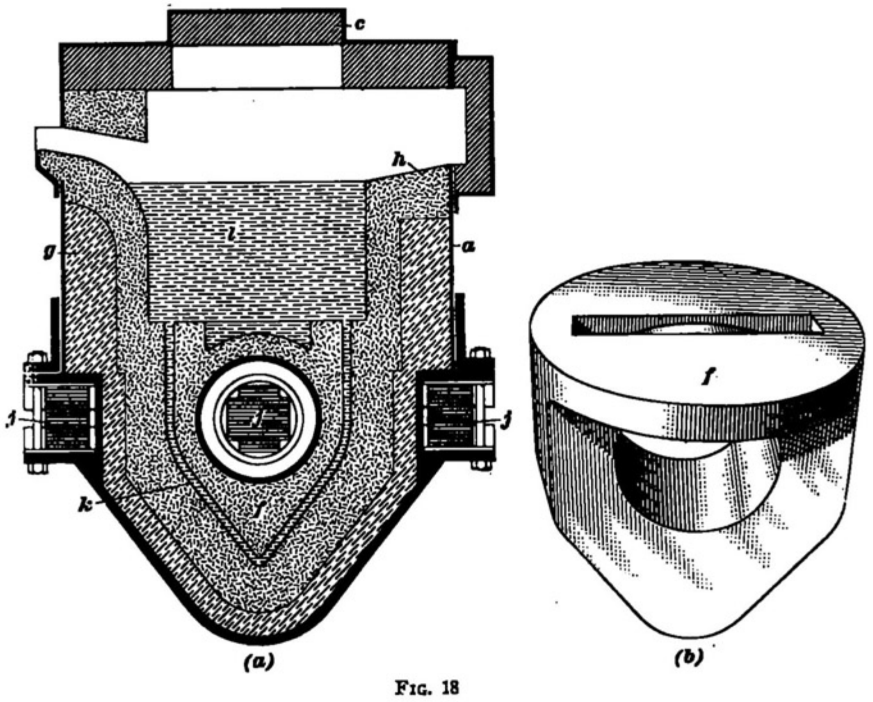


FIG. 17

21. Brass-Melting Induction Furnaces.—An induction furnace specially suitable for producing the lower melting temperatures, such as are required for the yellow brasses, and that heats the metal by utilizing the molten metal for its secondary electric circuit is shown in Fig. 17. This furnace consists of a cylindrical steel shell *a* having a **V**-shaped bottom *b* and a removable top *c*. The furnace is mounted in a tilting housing operated by the hand wheel *d*, and is shown in position for pouring the metal from a short spout *d′* in the front of the shell. The two primary wires from the power circuit are shown at *e*.



(a) (b)

FIG. 18

In Fig. 18 are shown a sectional view (*a*) of the furnace, Fig. 17, and a separate view (*b*) of the refractory center *f* of its **V**-shaped bottom. The shell *a* has a double refractory lining *g* and *h*. Alternating current from the power circuit passes through the coil protected by the refractory center *f*, and magnetizes the laminated core *j*. The induction from this alternating magnetization causes a heavy current to flow through the rather thin circuit of molten metal *k* surrounding the refractory center *f* in the **V**-shaped bottom. This current not only heats the metal but causes it to circulate vigorously, thus heating and mixing the body of metal *l* in the main part of the furnace. The heating and mixing are effective without any rocking or moving parts. The action of this type of furnace is silent. However, molten metal must be kept in the **V**-shaped bottom at all times during the operating periods, which necessitates keeping the current on. Furthermore, in order to start the furnace, at the beginning molten metal must be poured into it. In case the current were shut off and any metal were left in it, this metal would solidify, and it would be necessary to take the furnace apart in order to remove it. The temperature in a furnace of this kind is hardly high enough for red brass that contains a large percentage of copper; also, no alloy that might flux or endanger the lining, such as lead alloys, should be put in it.

22. Electric-Arc Brass-Melting Furnace.—One form of indirect-arc furnace for melting brasses and bronzes is shown in Fig. 19. It consists of a horizontal steel cylinder *a* having a thick refractory lining. The shell has two steel bands, or rails, *b* so that it may be revolved on the four flanged wheels *c*. Also there are two ring gears *d* around the shell, and these are meshed by pinions on a shaft located at the rear and driven by the motor *e*. During the melting period the shell is rocked back and forth through any part of a full term that may be desired by an automatic reversal of the driving system. The rocking action carries the metal over the heated lining, which promotes rapid melting and prevents uneven heating and overheating of the lining; it also mixes the metals and prevents segregation.

23. The melting in an indirect-arc furnace is done by the arc formed between the ends of two large carbon electrodes *f* that project into the furnace through the center of the end plates of the shell. Each electrode is clamped in an insulated crosshead *g*, to which the heavy electric cables *g'* are attached, and which is moved horizontally by two long feed-screws *h*.

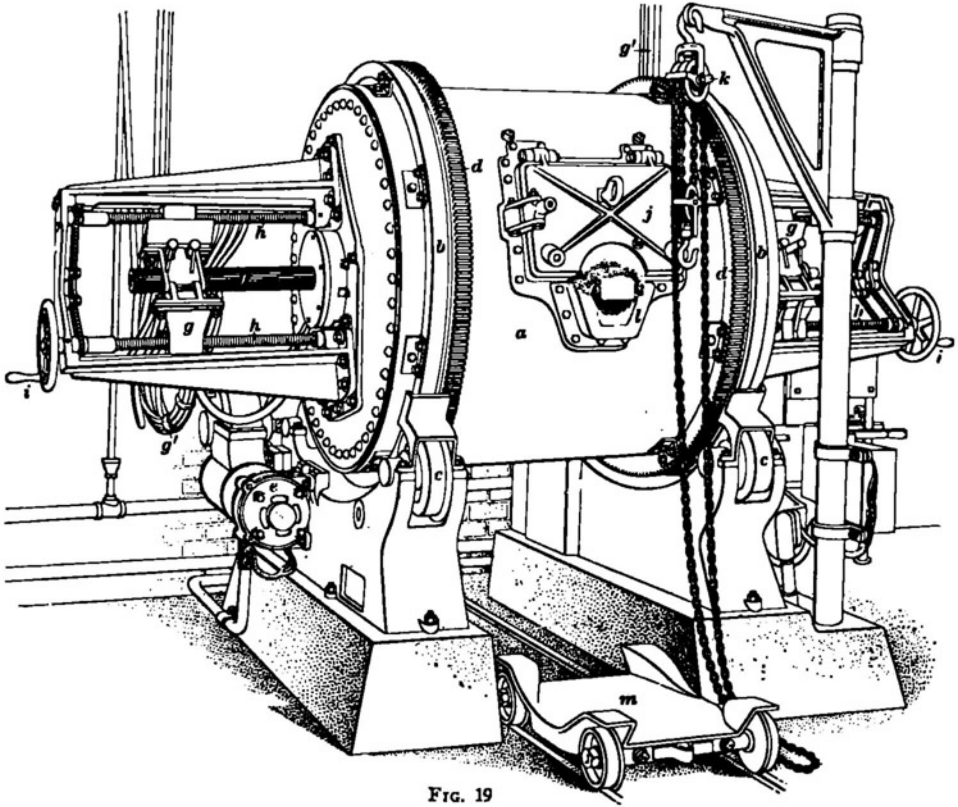


FIG. 19

The screws are operated by the hand-wheels *i* in order to move the electrodes. It is necessary to feed the electrodes into the furnace, as the arc gradually consumes their inner ends. A large and thickly lined door *j*, which may be lifted off by the chain hoist *k*, covers the opening needed for charging the pigs and scrap metals, and as a means for the workmen to enter the furnace to repair the lining. The pouring spout *l* is located under the door and is quite short, as the ladle may be set on a truck *m* and run under the furnace to be filled. A brick is used to close the spout during periods when it is desirable to prevent loss of heat and volatilized metals, or to exclude the air. A small opening is generally needed at the spout during some of the melting period for the escape of gases. Those from the burning impurities that may be on scrap metals, such as the oil on the brass turnings from the machine shop, are driven off early in the melting operation.

FURNACE PRACTICE

24. Melting Copper in Cupola.—Copper is sometimes melted in the cupola. The tin and zinc for the mixture should be added to the copper after it has been tapped from the cupola; or the other components of the desired alloy may be in the ladle in a melted state when the copper is drawn from the cupola. Sulphur will be absorbed from the fuel, if the alloy is mixed in direct contact with it, and metallic oxides will be formed; these, with the sulphur, may generate gases and so cause blowholes in the castings. Many founders who have tried to melt brass in a cupola have experienced this trouble.

Trouble from sulphur may be eliminated by using charcoal for fuel, but this, of course, raises the cost of melting. The metal in melting runs in drops or fine streams to the bottom of the furnace, passing, as it does so, through the live fuel. Practically all zinc that may be in the charge is lost and must be made up by subsequent additions to the metal in the ladle. The melting loss on bronze may run as high as 10 per cent. and the quality of the metal obtained is commonly poor. For these reasons, the cupola is little used for brass melting except in emergencies where no other means of melting large quantities of metal is available. In these emergencies, however, a satisfactory quality of metal can be produced if proper precautions are observed. It may be necessary to make an unusually large casting from an alloy that contains considerable tin, zinc, or lead. Sufficient melting capacity may not be available and a cupola furnace must be pressed into service. In this case, the fuel should be charcoal or a low-sulphur coke. Coke containing less than 1 per cent. of sulphur will prove satisfactory. Copper alone should be melted in the cupola and tapped out into a large bull ladle. Additions of tin, zinc, and lead may then be made to the metal in the ladle to bring the alloy to the desired composition.

25. Operation of Open-Flame Tilting Furnaces.—The open-flame furnace for melting brass, should be thoroughly heated before the first charge of metal is put in, as otherwise it will take an excessive amount of time to melt the charge. The metal may be charged either by hand or by mechanical means. The whole charge may be introduced at one time unless very light, bulky scrap is used, in which case it may be necessary to melt part of the charge before the rest can be introduced. When the furnace has been charged, the door should be closed and sealed with fireclay and the heat turned on. In order to shorten the melting period, the furnace should be rotated through approximately 180 degrees as soon as the metal has begun to soften. This should be repeated at fifteen-minute intervals throughout the melting period. Not only does this practice reduce the melting time, but it also tends to increase the life of the furnace lining by keeping it more nearly at the temperature of the molten bath. This rotation may be accomplished by hand or by power. Some furnaces are designed to revolve continuously during the melting period, being driven by an electric motor.

26. When the charge has been completely melted, the heat should be turned off and all slag skimmed off either through the pouring spout or through the charging door. This practice gives a cleaner metal for pouring, and it also reduces the melting period, as the slag, floating on the surface of the molten metal, acts as a heat insulator. After skimming, the heat is again applied, and the metal is brought up to the pouring temperature. When the furnace has been emptied, any slag which may be left in the bottom of the furnace should be carefully removed, any loose slag being pulled out with an iron hook. In order to insure that the slag is thoroughly removed, the furnace is tilted with the spout down, and an intense heat is applied for a few minutes. Any metal or slag that may have been left from a previous charge will thus be melted and will drip out of the furnace spout. Another method of cleaning a furnace is to wash the lining with molten copper. The copper wash, being at a high temperature, tends to melt and gather up any material that may be in the furnace.

If a number of different alloys are melted, each should be confined to a separate furnace if possible. Alloys that are similar, such as two red brasses of only slightly different chemical composition, may be safely melted in the same furnace, but good results would not be obtained from using the same furnace for red and yellow brass. If different furnaces cannot be used, the furnace must be thoroughly cleaned of all metal and slag from the previous heats, before the next alloy is melted.

27. There is a certain amount of pressure within the open-flame furnace during melting, and any metal that may have volatilized will be blown out with the exhaust heat. However, if good melting practice is observed, melting losses in the open-flame furnace will be no higher than in pit melting. Good practice calls for rapid melting and the emptying of the furnace as soon as the molten metal has been brought up to heat. If melting is slow or if the metal is allowed to remain in the furnace for an undue length of time, melting losses will become excessive.

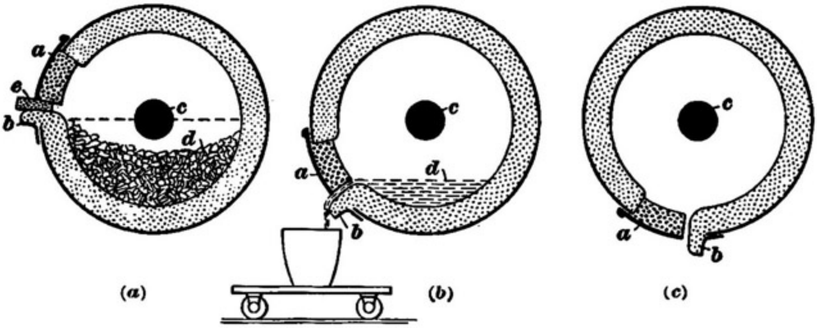
When it becomes necessary to reline the furnace, care must be taken to dry the lining thoroughly before the furnace is used. The lining should first be dried by a slow heat. A small wood fire may be built within the furnace itself. The more gradual and thorough the drying process, the less likelihood there is of the lining cracking subsequently. When the lining has been dried slowly, it is burned in by applying the direct heat of the furnace for a few hours. This hardens the lining and makes it capable of resisting wear.

OPERATING ELECTRIC FURNACES

28. General Requirements of Electric Melting.—The electric furnaces used for brass melting require much less current than those for steel and cast iron because the temperature needed is lower. There is considerable loss of heat from all classes of furnaces, so that with electric types, where the power is usually more expensive than for the others, special care should be taken to prevent excessive losses. The heat insulation and refractory linings should be kept in good repair and up to their maximum thickness, the furnace should be kept closed to the greatest extent possible for the purpose of holding the metal vapors in and keeping the air out, and, most important of all, the time between charges should be shortened to the utmost. The cooling off of the furnace between heats means an increase of the amount of electric current, and hence the cost, of the daily operation.

29. It is not necessary to be an electrical engineer in order to operate electrical melting furnaces, as most of the operation is of a mechanical nature. On the other hand, in order to install such furnaces and to supervise their production for the greatest safety to the operators and the furnace, and for the highest efficiency, a knowledge of electrical engineering is desirable if not absolutely essential. Therefore, those who expect to get to the top in the large industry of electric heating should pursue a course of electrical studies.

30. Induction-Furnace Operation.—In order to start the induction furnace it is necessary to preheat it with oil or gas burners, and then to fill the space in the **V**-shaped bottom with molten metal. This metal must be supplied from some other furnace. After the **V**-shaped bottom has been charged, the current must be kept on at all times while there is any metal in it. The furnace crucible is then charged with solid metal. As there are no electrodes in the induction furnace, no reducing or neutral atmosphere is produced over the metal. Therefore, it is necessary to cover the metal with charcoal to prevent metal losses and the driving off of poisonous fumes. The whole charge of solid metal is put in at once, and all but that in the **V**-shaped bottom is poured out when immediate recharging is intended. Induction furnaces are used largely for melting yellow brass, as the temperatures produced are not so high as in the indirect-arc furnace.



(a) (b) (c)

FIG. 20

31. Indirect-Arc Furnace Operation.—The operation of an indirect-arc furnace, of either the rocking or the revolving type, assuming that the linings are in good order as required by all electric furnaces, begins with the charging. The door *a*, Fig. 20 (*a*), is lifted off by the swinging, or jib, crane and the spout *b*, is set either at the top or above the horizontal. The electrodes *c* must be withdrawn so as to be out of the way and also to prevent breaking them when throwing in and placing the solid metal. The metal is usually charged by hand, aided sometimes by a chute or bucket and a hoist. The solid metal *d* is banked against the lining and around and clear of the position occupied by the electrodes *c*. The electrodes must not be covered by the metal, as the direct heat from the arc is so intense that there would be a considerable loss of metal, and some danger to the operators from poisonous metallic fumes. No covering is put on the metals. The electrodes are then put in position with their ends slightly apart and the switch closed. They are then separated slightly and the arc is drawn to whatever extent will give the best results. The door must be set on tightly, but the spout is generally left open until the smoke or gases from the impurities are driven off. It is then closed by the plug *e*.

32. As soon as some of the charge is melted, the rocking action may be started. Only a slight rock is possible at first because the solid metal is liable to fall onto the electrodes, but a gradual increase is made until the molten metal is finally brought into contact with all the heated lining except that of the door and at its sides. Sometimes it is necessary to open the spout to skim the metal and to take its temperature with a pyrometer. Care should be taken to prevent overheating or prolonged heating, as this means losses of both power and metal and may aggravate the production of dangerous metallic fumes that are common from overheated copper and some of the alloys. The furnace room should be extra well ventilated at all times, no matter what type of furnace is used. The furnace spout is brought low for pouring, as shown in Fig. 20 (*b*). It is then brought clear to the bottom for cleaning, as in (*c*), after which it is revolved back to the charging position shown in (*a*). A complete record should be kept of the weights of metals charged and poured, meter readings, time of all events, repairs, electrode consumption, etc.

The operation of the revolving furnace is similar to that of the rocking furnace described above, except that the furnace makes complete revolutions instead of the back and forth motions. The spout and charging door of the revolving furnace are in the end of the cylindrical shell, which makes it possible for a complete revolution of the shell. The indirect-arc furnaces are used largely for melting red brasses, which require a higher temperature than the yellow brasses. However, by careful attention to prevent overheating, yellow brasses may be melted also in these furnaces.

33. Using Waste Heat From Melting Furnaces.—The uses to which the waste heat from melting furnaces in the brass foundry may be put are numerous. In some instances the heat is used for annealing crucibles, in others for warming storage rooms for baked cores, or even for heating core ovens, no other heat being supplied. Some foundries are heated entirely by waste heat from the furnaces, and in addition the heat may be used to heat fuel and lubricating oil, water, etc. No standard system of utilizing waste furnace heat has been devised, but each plant has its own way according to the conditions prevailing.

MELTING PRACTICE

34. Oxidizing and Reducing Atmosphere.—To obtain the most efficient melting conditions in a brass foundry, the combustion of the fuel used should be complete. If carbon is burned to carbon dioxide it yields about 14,500 B.t.u. per pound, whereas if it is burned only to carbon monoxide it yields only 4,380 B.t.u. per pound or about 30 per cent. of its full value. Thus for efficient melting, no unburned carbon monoxide should pass out of the furnace. To secure this, air somewhat in excess of that theoretically required for complete combustion must be supplied to the furnace. The result is a flue gas of an oxidizing character. All of the component parts of ordinary brass are readily oxidized at the temperatures to which they must be heated for pouring. Oxidization results in a loss of metal, since the oxides form a dross that must be skimmed off. In addition, some oxides do not separate readily from the metal. These are held in the metal either in solution or mechanically and seriously affect the strength and quality of the finished casting. Hence, it is necessary to sacrifice some combustion efficiency in order to maintain a reducing atmosphere within the furnace.

A reducing atmosphere is maintained by permitting a certain amount of carbon monoxide to remain unburned. The amount that should be present in the gases varies with the type of furnace and other conditions. To obtain the best efficiency it should be just high enough to prevent oxidization and no higher. The electric furnace generally operates with a neutral or slightly reducing atmosphere at no sacrifice of heat efficiency and therein has a great advantage over the other types of furnace.

35. Melting Losses.—Aside from actual oxidization, metal is lost through volatilization. Of the metals used in making brass, zinc is the most highly volatile and the greatest attention must be paid to the reduction of zinc losses. The reason for this is that if the zinc losses are low, the losses of other metals in the brass will likewise be low. Zinc melts at 785° F. and boils at 1,690° F. under atmospheric conditions. It has an appreciable vapor pressure at temperatures only slightly higher than its melting temperature. Copper-zinc alloys in common use, that is, those containing up to 30 per cent. of zinc, melt at from about 1,733° F. to 1,994° F. and are poured about 300° hotter. The boiling points of copper-zinc alloys range from about 2,100° F. for an alloy containing 30 per cent. of zinc to 4,200° F. for nearly pure copper. Thus as the percentage of zinc in the alloy increases, the proximity of the pouring temperature to the boiling point of the alloy also increases, and hence the tendency for the zinc to volatilize increases. Thus the zinc losses are a great deal heavier in high-zinc alloys than in low-zinc alloys.

36. The rate at which zinc volatilizes depends on the composition of the alloy, the maximum temperature to which it is heated, the rate of heating, the volume and velocity of the gas that flows over the surface of the metal, and the pressure within the furnace. The composition of the alloy and the temperature to which it must be heated are dependent on the casting specifications and characteristics. Rapid melting and the prompt pouring of the metal are essential to low-zinc losses. Speed of melting varies with the type and capacity of the furnace employed. For a given type, the larger the charge of metal melted the smaller is the time required per 100 pounds of metal used for melting. In charges of less than 500 pounds this reduction in time is very marked.

37. Volatilization of zinc lessens as the pressure in the furnace increases. In the open-flame furnace, good practice dictates that all openings be as small as possible so that the maximum pressure may be obtained. The pressure, however, should not be raised by increasing the velocity of flow of the furnace gases. If there were no flow of gases out of the furnace, the atmosphere above the metal would soon become saturated with zinc vapor and no further loss would result. This condition is approached by certain types of electric furnaces, notably the induction furnace, and accounts partially for the low metal losses suffered in this type. In the other fuel-burning furnaces, there must be a continual flow of gases to remove the products of combustion. As the rate of flow increases, the metal losses will increase, other conditions being constant. The rate of volatilization becomes slower as the saturation point of the gas above it is approached. Thus the smaller the volume of gas above the metal, other things being equal, the more nearly saturated it will be and hence the smaller will be the metal losses by volatilization. To sum up, in order to secure the minimum loss of metal during melting, the rate of melting and the pressure within the furnace should be as great as possible, and the volume and velocity of the flue gases as small as possible. In order to reduce the metal losses to a minimum, the metals having the lower melting points such as zinc and lead are added to the charge near the end of the melting period. This may be done immediately after skimming, or the additions may be made to the individual ladles just before pouring. The latter practice reduces losses to a minimum, but it tends to cool the metal in the ladle to a certain extent.

38. Coverings and Fluxes.—A covering over the surface of the molten brass, either in the form of a solid cover or of a molten flux will greatly lessen the volatilization of zinc. Solid covers have been used over crucibles, but this practice greatly increases the melting time and hence is not recommended. The flux that is used probably more than any other is common salt.

With it is sometimes mixed silica, sand, and broken glass. The salt forms a molten covering over the surface of the metal and serves also as a flux for metallic oxides. As a cover, it tends to lessen the volatilization of zinc and also prevents the occlusion of gases. A layer of charcoal is often floated on the surface of the molten metal with or without the flux, particularly in melting pure copper. The charcoal in burning produces a layer of carbon monoxide directly over the surface of the metal, which prevents oxidization to some extent. Another flux recommended consists of one part fluorspar to three parts lime, together with some hard coal.

39. Ladle Coverings.—When the metal is transferred from the furnace to the mold in a ladle, the metal in the ladle should be covered. Charcoal, salt or plain molding sand is used for this purpose. It is thrown into the ladle at the furnace and skimmed off just before pouring. The value of such a covering is shown by the great increase in zinc-oxide clouds present at the moment the metal is skimmed. The surface of the sprues and risers in the mold are sometimes covered with dry sand after pouring, particularly if pure copper is used. The dried sand acts as a heat insulator, keeping the metal in the sprues and risers fluid for a longer period of time, thus aiding the feeding of the metal to the casting.

40. Gas Absorption.—Melting should be done so that as little gas as possible will be absorbed by the metal, or else porous or spongy castings will result. Gas is absorbed by molten metal principally by solution. Carbon dioxides, carbon monoxide, nitrogen, oxygen, sulphur dioxide, and water vapor are all usually present in the exhaust gas. Of these, oxygen is usually the most troublesome. Copper has the property of absorbing oxygen in large quantities, the amount absorbed increasing with the temperature. On cooling, the oxygen is liberated. If the cooling is rapid, all of the gas will not be able to escape and the result will be a casting full of blow holes.

Gas absorption may be kept at a minimum largely by careful furnace practice. It is better and easier to keep gas out of the metal during melting than to try to eliminate it afterwards.

In attempting to do the latter, castings are sometimes poured very hot so that the gas may be liberated before the metal sets.

A somewhat contradictory practice is to cool the metal to the lowest possible pouring temperature on the theory that most of the gas will be released before the metal is poured. Even with the most careful melting, it is well to add a deoxidizer to each ladle or crucible of pure copper before pouring. A small quantity of silicon, phosphorus, titanium, common salt, beryllium, or boron suboxide will answer the purpose. Carbon dioxide gas is sometimes blown through the ladle of molten metal.

41. The carbon dioxide is not soluble itself but will unite with and carry out other gases. As an additional check, the molder should test the first ladle of metal of every heat before pouring. This he may do by making a cylindrical hole in compacted molding sand with a sprue-hole cutter and pouring it full of molten copper. The hole should be about 1 inch in diameter and 4 inches deep. The exposed surface of metal should be covered with dry sand and the bar allowed to set. If the surface of the bar is convex or if the metal "comes up," the metal contains gas and is unfit for pouring. If the surface is flat or slightly concave, the metal may be poured. When the metal comes up, it should either be deoxidized by the addition of a deoxidizer or should be returned to the furnace and poled, as explained later.

To keep down gas absorption, the metal should be melted as rapidly as possible, a slightly reducing atmosphere should be maintained in the furnace, and a suitable covering should be used. It is easier to prevent gas absorption in natural-draft crucible furnaces than in open-flame furnaces, although it is entirely possible to produce metal free from gas from the latter type if care is exercised. Little trouble from gas absorption is experienced in the electric furnace.

42. Poling.—Copper and alloys of copper may be deoxidized without the addition of any other metals than those the alloy is supposed to contain. This result is accomplished by stirring the mixture with an unseasoned hardwood stick. This operation is commonly called *poling*. The gases produced by the burning wood set up a motion within the molten metal, which mixes the charge and at the same time deoxidizes it. The same effect is sometimes accomplished by throwing a few turnips or potatoes into the furnace. Steam is sometimes blown through the metal, but the steam must be thoroughly dry; otherwise, it may cause an explosion. Poling should be continued until a sample of the metal will cool without showing either a depression or an elevation in the center. When copper or a copper alloy is overpoled, its strength is reduced. While poling, its surface must be kept covered with a layer of charcoal, which protects it from contact with air and thus prevents the oxidation of the metal.

Poling is impossible when the metal is being melted in a crucible, because the small quantity of metal is readily chilled and the loss by the slopping of the metal is apt to be rather large. Deoxidation under these conditions may be accomplished by means of manganese, phosphorus, or some similar deoxidizing agent.

43. Deoxidizing With Silicon Copper.—Silicon copper is an alloy of silicon and copper used to remove such gases as oxygen and some of the oxides from copper, brass, and bronze. Silicon copper may contain from 10 to 30 per cent. of silicon. The 10-per-cent. grade is, however, the most common. In adding silicon copper, care should be exercised to see that no more is added than is needed to remove the oxygen. If any considerable quantity of silicon remains after the oxygen has been removed, it enters the metal, hardens it, makes it brittle, and tends to produce holes in the castings.

44. Deoxidizing With Phosphorus.—The addition of phosphorus to bronze makes the metals of which the bronze is composed unite more closely than they would without it. The metals that would otherwise be subject to segregation may be used in larger proportion than would be possible without the phosphorus. Some metals that are alloyed combine with difficulty; others form oxides or absorb a gas and both the oxides and the gas will be injurious to the castings. On account of the ease with which phosphorus catches fire, it is kept under water. It should never be handled with bare hands and care should be exercised to see that none of it comes in contact with the clothing, on account of the burns that it will produce. In order that the phosphorus may be handled more readily, it is sometimes covered with a coating of copper in the following manner: After having prepared a dilute solution of copper sulphate, or blue vitriol, the sticks of phosphorus are transferred from the water in which they have been kept to the blue-vitriol solution, where they are left for about 30 minutes, or until a good coating of copper has been obtained. The use of the blue-vitriol solution is not without its disadvantages, since it is poisonous and will produce a bad sore if it touches a place where the skin is broken.

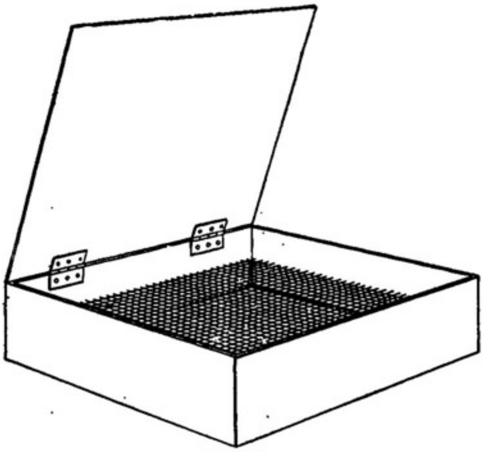


FIG. 21

When the sticks of phosphorus are taken from the blue-vitriol solution they should be placed on a piece of blotting paper in a pan like that shown in Fig. 21. This pan is about 6 inches deep and should contain about 2 inches of water over which is placed a wire netting for the blotting paper to rest on. The pan is also provided with a cover so that in case the phosphorus catches fire the cover may be closed tightly and the fire smothered.

45. The best way of adding phosphorus to the melted metal is by means of a phosphorizer. A phosphorizer is a clay or graphite tube *a*, Fig. 22, which is fastened to the end of an iron rod *b*. The sticks of phosphorus are put in this tube and a piece of tin or copper or even a piece of paper may be fastened over the end of the tube to hold the phosphorus in the tube until the phosphorizer can be plunged into the metal. The phosphorizer is held in the metal until all the phosphorus has been absorbed.

46. While the phosphorus is being absorbed, the metal is violently agitated and a considerable amount may spatter out of the crucible and be lost. In order to prevent the spattering of the metal, the phosphorizer may be provided with a metal disk that fits over the handle *b*, Fig. 22, at the point where it is attached to the phosphorizer tube. When the phosphorizer is placed in a crucible, this disk forms a cover and prevents the metal from spattering out. Another method of preventing the loss of metal from the crucible is to increase its height by placing an old crucible, from which the bottom has been cut, upside down on top of it and closing the joint with a little mud.

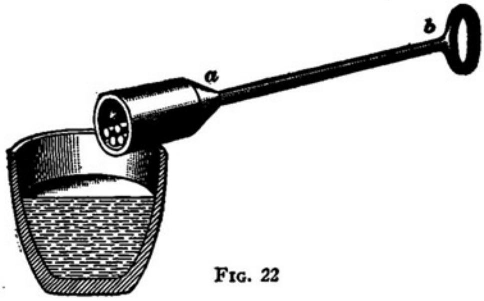


FIG. 22

Phosphorus may also be added in the form of phosphor copper or phosphor tin. The phosphor copper is made in two grades, one containing 10 per cent. of phosphorus and the other 15 per cent. Phosphor tin contains about 5 per cent. of phosphorus. The amount of phosphorus contained in phosphor copper may be expected to be quite uniform, so that the maker will usually guarantee it to be as specified. The phosphorus content of phosphor tin is, however, less uniform and it should always be checked by chemical analysis. Should more phosphorus than is needed to remove the oxygen be added to the metal, the excess may alloy with the metal and make the resulting castings brittle and very hard.

47. Making Non-Ferrous Alloys.—Non-ferrous alloys may be made by melting together the constituent metals, by compressing their mixed powders or by an electro-chemical process. The first method is the one used ordinarily. One of the metals, usually that of the highest melting point, is melted, and the others sometimes in the molten state, but often in the solid, are added to it.

Alloys have very different physical characteristics from those possessed by their constituent metals. Some metals, such as aluminum and copper, evolve heat when alloyed. Other metals, such as lead and tin, absorb heat when they unite. One part each of powdered tin, lead, and bismuth mixed with eight parts of mercury will freeze water. Alloys are not made to any extent by compressing their powders, but brass and various alloys of gold may be made commercially by electro-deposition.

48. Non-ferrous metals that have been united by fusion do not always remain united if they are allowed to cool slowly or sometimes even if cooled rapidly. That portion of the alloy which forms first may reject certain other portions of the constituent metals. This action of separation of the metals is called *liquation*. The most fusible alloy that is left is called the *eutectic alloy*. While a eutectic alloy is not a chemical compound, its composition is fixed and its properties definite. Naturally, the brass founder will prefer to use a eutectic alloy because of its lowest melting point, or if this is impossible, he will use an alloy with a minimum of liquation. When it is necessary to make an alloy, as, for instance, one containing 50 per cent. of lead that is apt to liquate, the liquation may be prevented considerably by adding a small amount of sulphur. This causes a rapid solidification of the molten mass of copper and lead when poured into castings and the liquation of lead is prevented.

49. Melting Aluminum Alloys.—Aluminum-alloy-melting practice differs from brass-melting practice in several minor respects, and several additional precautions must be observed. Almost any of the types of the furnaces that are used for brass melting may be used for the melting of aluminum alloys, though they are commonly melted in cast-iron-pot furnaces. Pressed steel pots are sometimes used. The fuel used with crucibles may be oil, coke or gas. Iron pots are heated by oil or gas and are not covered. Explosions sometimes occur from charging wet or coated aluminum into pots of molten metal. In open-flame furnaces the quality of metal produced is usually poor.

50. Aluminum does not volatilize readily at ordinary melting temperatures, and hence coverings are not used to any extent where the products of combustion do not make contact with the metal. Considerable trouble is experienced from blowholes and porosity in castings made from aluminum alloys. Unsoundness is caused by the presence of gas trapped in the casting at the time of solidification. The remedy is to pour the metal as free of gas as possible. The amount of gas present in the metal is dependent chiefly on the temperature to which it is heated, the length of the melting period and the atmosphere of the furnace. To obtain sound castings, the metal should be heated to the lowest temperature consistent with fluidity for pouring and as rapidly as possible in a neutral or slightly reducing atmosphere. The pouring temperature should be as low as possible. Fluxes for the deoxidization of aluminum alloys are considered of doubtful value. Kryolite and chloride of zinc are the fluxes commonly used.

51. In melting aluminum alloys in iron pots, the aluminum tends to dissolve iron from the walls of the container. If scrap is remelted time and again in an iron pot, the iron content is likely to become so high that the metal must be refined before it can be used successfully. When the molten metal is bailed from an iron pot with a ladle, the walls are washed with a thin coating of the aluminum alloy. This attacks the iron and an iron-aluminum compound is formed. Pieces of this compound may be subsequently chipped off during bailing. This iron-aluminum scale is insoluble in aluminum and hence tends to form hard spots in the finished casting, adding greatly to machining and polishing difficulties. When melting is done in clay crucibles, silica is often introduced into the alloy. This may be an advantage where the castings are to resist corrosion, as castings for teakettles. In addition, non-metallic hard spots may be caused by the chipping or scalping of the crucible, particularly if it is old. Careful and intelligent melting practice will tend to minimize these troubles.

BRASS-FOUNDRY CRUCIBLES AND LADLES

52. Composition of Crucibles for Brass.—Crucibles that are used in the brass foundry are commonly made of graphite, which is generally known as plumbago, or black lead. The best graphite for this purpose is almost pure carbon, which is obtained from Ceylon. Since pure graphite contains no material that will hold it together, it is necessary to add something for that purpose. A small quantity of pure fireclay is used to bond the graphite and a little silica sand is added to the crucible mixture so that it will be able to expand and contract without cracking.

When graphite crucibles are to be used for the melting of nickel or an alloy of nickel they are lined with about ¼ inch of fireclay. The clay lining prevents the nickel from absorbing graphite from the crucible; graphite would spoil the castings.

The brass founder often looks on light-colored crucibles with disfavor, thinking that they are deficient in graphite. The light color means only that, in firing the crucible, a small amount of graphite was burned from the outside layer, leaving only the white clay showing. Such a crucible often gives a larger number of heats than one that has a darker color.

The graphite and clay used in crucible making, sometimes contain sulphur, iron, or arsenic, called sulphur balls. These materials are injurious to the metal and should be avoided.

53. Capacities of Crucibles.—Table I gives the diameter of crucibles and the pounds of copper they will hold, as well as the numbers by which they are sold by dealers. The table is based on the supposition that a No. 1 crucible, when level full, holds 3 pounds of melted copper, and for each increase in number there is an increase of 3 pounds in capacity. If it is desired to test the capacity of a crucible, it may be varnished on the inside, filled with water, and weighed. The difference between the weight of the crucible when full of water and when empty multiplied by 8.8 gives the weight of copper that the crucible will hold.

TABLE I

SIZE AND CAPACITY OF CRUCIBLES

Number of Crucible	Outside Height Inches	Greatest Outside Diameter Inches	Capacity in Melted Metal Pounds
1	3½	3	3
2	4	3¼	6
3	4⅝	3¾	9
4	5⅛	4¼	12
5	6	4⅝	15
6	6½	5⅛	18
8	7¼	5⅞	24
10	8¼	6¼	30
12	8⅝	6½	36
14	9⅛	7¼	42
16	9⅝	7¾	48
18	10	8⅛	54
20	10⅝	8⅝	60
25	11⅛	9	75
30	11¾	9⅜	90
35	12¼	9¾	105
40	12⅝	9⅞	120
45	13	10½	135
50	13¾	10¾	150
60	14⅛	11¼	180
70	14¾	11¾	210
80	15½	12½	240
100	16⅛	13	300

When it is desired to find the weight of any of the metals named in Table II that may be melted in one of these crucibles, divide the weight of copper that the crucible will hold, by 8.8 and multiply by the number given opposite the name of the metal in Table II.

54. Care of Crucibles.—If the crucibles used in melting brass are handled carefully they will last for thirty or more heats; if they are handled carelessly or ignorantly, they may be crushed or cracked in one or two heats. The first thing necessary to prolong the life of a crucible is to anneal it thoroughly so as to drive out the moisture. Annealing is done by heating the crucible for several days to a temperature of 220° F. or about that of core ovens. Crucibles are usually annealed when they are made; but during transportation they absorb moisture, which must be driven out to avoid cracking the crucible when it is in use. In the case of large crucibles, it is well, after anealing them, to keep them mouth downwards over a slow fire for 6 or 8 hours. A sufficient number of crucibles should be kept in stock, so that any that are partly glazed may be saved for heavy heats or any especially hot firing that may be required.

TABLE II

FACTORS FOR FINDING CAPACITIES OF CRUCIBLES

Metal	Factor	Metal	Factor
Copper	8.80	Phosphorus	1.83
Tin	7.29	Silicon-copper ..	7.70
Zinc	7.15	Nickel	8.80
Lead	11.37	Magnesium	1.74
Aluminum	2.56	Antimony	6.70
Manganese	7.50		

A crucible used where the melting is done in from 1½ to 1¾ hours, under forced draft, cannot last as long as one where from 2 to 4 hours are taken in the melting. The character of fuel used may also have much to do with the life of a crucible. If the draft or damper is regulated in such a manner as to produce an oxidizing instead of a reducing flame, the life of the crucible will be shortened.

55. The kinds of metals melted also are important factors. A crucible that will last only three heats when melting nickel may last six heats with steel, twenty-five heats with copper, and possibly may be used forty times when melting the soft compositions.

In charging furnaces, the metal should not be jammed into the crucible, as it may be strained and cracks caused. In using the tongs, they should be made to fit the crucible closely, as otherwise the parts with which they are in contact will be strained.

After pouring the metal out of the crucible, care should be taken to see that none remains in the bottom, as it will adhere to and tear the bottom when it has cooled, or while being removed when the crucible is being prepared for the next heat.

When the heat is finished, the crucible should be stored away in some warm, dry place, until the next heat; and if this interval lasts more than a few days, it should be put in the core oven and heated before being used again.

In ordering crucibles, it is well to inform the manufacturer of the kind of metal for which they will be used; he will thus be enabled to select a mixture for the crucible that will be suitable for the intended work.

56. Pinholes are defects in the crucibles that sometimes do not appear until after several heats have been taken. Pinholes are usually made apparent by a small stream of metal running down the side of the crucible. They are probably caused by raising the temperature of the crucible too rapidly when annealing it. The moisture that the crucible has absorbed is thus turned into steam more rapidly than it can escape and the crucible is cracked. Under certain conditions this action may be so aggravated that the crucible may be broken, or pieces may be chipped off the sides. When pieces are broken from the crucible in this way, the crucible is said to have *scalped*.

Crucibles may also be injured when fixing the fire by striking them with the poke bar or by ramming the fuel too tightly against them. When the crucible is lifted from the furnace, clinkers may adhere to it. If so, they should be removed at once, as they may become so hard when cold as to injure the crucible if the tongs should happen to grip over them.

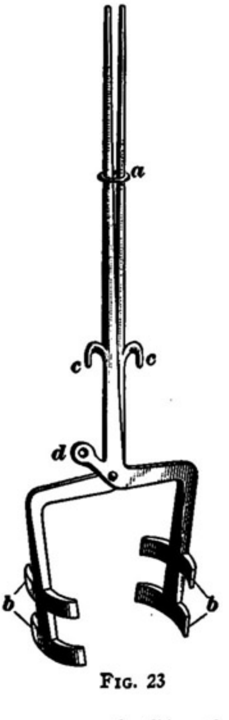


FIG. 23

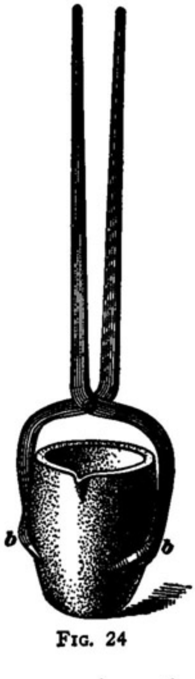


FIG. 24

57. Tongs and Shank.—When removing the crucible from the furnace with the tongs, care must be taken that the jaws *b*, Figs. 23 and 24, of the tongs are below the largest part of the crucible, as is shown in Fig. 24, otherwise, the pot may slip out of the tongs before it reaches the top of the furnace or as it is being carried around the floor, thus spilling and losing the metal and endangering the workmen. When the tongs clasp the pot, a link *a*, Fig. 23, is slid along the handles, as shown, and made to press them tightly together;

the pot can then be lifted from the furnace. If the pot is too heavy for one man to handle, it is lifted by two or more men. When the crucible is very heavy, a chain hoist is used, the hoisting chain being hooked on one of the hooks *c* or attached to the eye *d*, Fig. 23. Sometimes the hoists are suspended from overhead rails or trolleyways that permit of the crucible being carried from the furnace to the mold while it is suspended in the lifting tongs; or it may be lowered into a ladle shank *a*, as shown in Fig. 25.

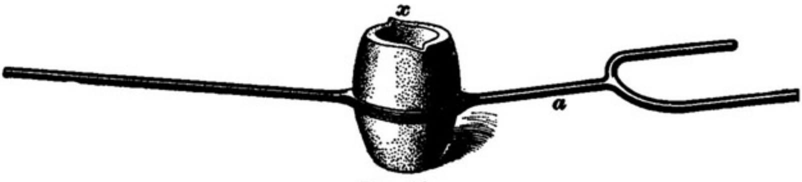


FIG. 25

58. In pouring by the use of ladle shanks, the crucible may be kept from tipping out of the shank by using a clamp that is attached to the shank and that hooks over the edge of the crucible.

The tongs shown in Fig. 26 are a modification of the design shown in Fig. 23. They are intended to be used with a crane for lifting crucibles that are too heavy to be lifted from the melting furnace by hand. The crane hook is attached to the ring *a* and the weight of the tongs then causes them to close over the crucible.

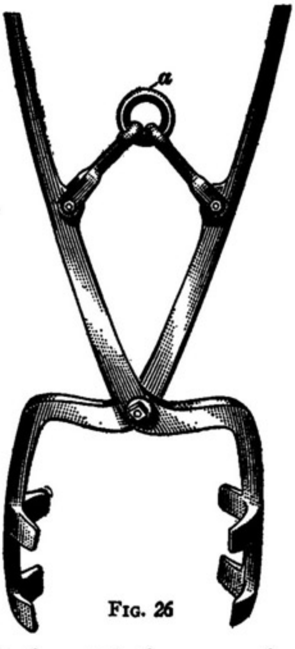


FIG. 26

The crucible usually holds more melted metal than can be put into it at the first charge. When the first charge settles, fresh metal may be added by using the tongs shown in Fig. 27.

59. Ladles.—Metal that is melted in any of the brass furnaces other than the portable-crucible type, must be transferred from the furnace to the mold by ladles. These may be small enough to be carried by two or three men or they may be moved about by a crane, depending on the size of the mold to be poured. In some instances, the furnace itself is moved about for pouring, but this practice is not common.

A typical ladle designed to be carried by three men will hold about 200 pounds of metal. The ladle shell is made of $\frac{3}{16}$-inch sheet steel and is permanently fastened to the carrying shank. The shell is lined with a mixture of loam and fireclay to a thickness of about 1 inch. This lining must be thoroughly dried before the ladle can be used. This is accomplished either by building a wood fire within the ladle itself or by placing the ladle under an oil or gas warmer. Drying may be made more thorough if waxed strings such as are sometimes used for venting cores are placed in the lining midway beween the inner surface of the lining and the ladle shell. When heat is applied, the wax melts and the string burns. Thus passageways or vents are made through which moisture will be driven off. Large ladles may be dried by suspending them with a crane over the mouth of an open-flame tilting furnace, although this intense heat is likely to dry out the lining more quickly than is desirable unless the ladle has been initially warmed by a slower flame.

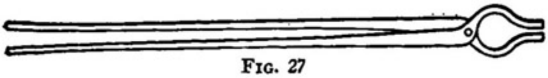


FIG. 27

It is good practice to carry alloys that are chemically dissimilar, in separate ladles; otherwise impurities are almost certain to be introduced into the metal. After each ladle of metal has been poured, any excess metal that remains should be poured into chills to be remelted later. At the end of each heat, the ladle should be thoroughly cleaned with a heavy iron bar and placed under a warmer until again needed.